

(NASA-CR-144320) EXPANSION AND IMPROVEMENT N76-25573

OF THE FORMA SYSTEM FOR RESPONSE AND LOAD

ANALYSIS. VOLUME 2G: LISTINGS, FINITE

ELEMENT FORMA SUBROUTINES (MARTIN MARIETTA UNCLAS

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# EXPANSION AND IMPROVEMENT OF THE FORMA SYSTEM FOR RESPONSE AND LOAD ANALYSIS

Volume IIC - Listings, Finite Element FORMA Subroutines

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## FOREWORD

This report presents results of the expansion and improvement of the FORMA system for response and load analysis. The acronym FORMA stands for FORTRAN Matrix Analysis. The study, performed from 16 May 1975 through 17 May 1976 was conducted by the Analytical Mechanics Department, Martin Marietta Corporation, Denver Division, under the contract NAS8-3137. The program was administered by the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville, Alabama under the direction of Dr. John R. Admire, Structural Dynamics Division, Systems Dynamics Laboratory.

This report is published in seven volumes:

Volume I - Programming Manual,

Volume IIA - Listings, Dense FORMA Subroutines,

Volume IIB - Listings, Sparse FORMA Subroutines,

Volume IIC - Listings, Finite Element FORMA Subroutines,

Volume IIIA - Explanations, Dense FORMA Subroutines,

Volume IIIB - Explanations, Sparse FORMA Submoutines, and

Volume IIIC - Explanations, Finite Element FORMA Subroutines.

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#### **ABSTRACT**

This report presents techniques for the solution of structural dynamic systems on an electronic digital computer using FORMA (FORTRAN Matrix Analysis).

FORMA is a library of subroutines coded in FORTRAN IV for the efficient solution of structural dynamics problems. These subroutines are in the form of building blocks that can be put together to solve a large variety of structural dynamics problems. The obvious advantage of the building block approach is that pr gramming and checkout time are limited to that required for putting the blocks together in the proper order.

The FORMA method has advantageous features such as:

- 1. subroutines in the library have been used extensively for many years and as a result are well checked out and debugged;
- 2. method will work on any computer with a FORTRAN IV compiler;
- 3. incorporation of new subroutines is no problem;
- 4. basic FORTRAN statements may be used to give extreme flexibility in writing a program.

Two programming techniques are used in FORMA: dense and sparse.

## ACKNOWLEDGMENTS

The editor expresses his appreciation to those individuals whose assistance was necessary for the successful completion of this report. Dr. John R. Admire was instrumental in the definition of the program scope and contributed many valuable suggestions. Messrs. Carl Bodley, Wilcomb Benfield, Darrell Devers, Richard Hruda, Roger Philippus, and Herbert Wilkening, all of the Analytical Mechanics Department, Denver Division of Martin Marietta. Corporation, have contributed ideas, as well as subroutines, in the formulation of the FORMA library.

The editor also expresses his appreciation to those persons who developed FORTRAN, particularly the subroutine concept of that programming tool.

## I. INTRODUCTION

A listing of the source deck of each finite element FORMA subroutine is given in this volume to remove the "black box" aura of the subroutines so that the analyst may better understand the detailed operations of each subroutine.

The FORTRAN IV programming language is used in all finite element FORMA subroutines.

## II. SUBROUTINE LISTINGS

The subroutines are given in alphabetical order with numbers coming before letters.

```
SUBROUTINE AXIAL (XY2, JDC)F, EUL, NUTEL, NJ,
                         NUTMX, NUTKX, NUTLT, NUTST,
                         W. T. S. KX, KJ, KE, KW)
      DIMENSION XYZ(KX,1),JDDF(KJ,1),EUL(KE,1),W(KW,1),T(KW,1),S(KW,1)
      DIMENSION CJ(3,2), Ed(3,2), IV1(6)
      DATA NAMEL/6HAXIAL /, NRW, NRLT/6, 2/, IBLNK/6H
                                                          /, KCJ/3/
      DATA NIT, NOT/5,6/
-C
   SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT ...
C
      MASS MATRICES AND IVECS (ON NUTMX),
- C
      STIFFNESS MATRICES (SAME AS GLOBAL LOAD TRANSFORMATION MATRICES)
C
      AND IVECS (ON NUTKX),
C
      LOCAL LOAD TRANSFORMATION MATRICES AND IVECS (ON NUTLT).
C
      STRESS TRANSFORMATION MATRICES AND IVECS (ON NUTST)
C
   FOR AXIAL POD ELEMENTS.
   MASS. STYFFNESS MATRICES ARE IN GLOBAL COORDINATE DIRECTIONS.
C
C
   GLOBAL COORDINATE ORDER FOR EACH ELEMENT IS
C
      (U,V,W) JOINT 1, THEN JOINT 2.
C
   WHERE U, V, W ARE TRANSLATIONS.
C
   IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
C
      IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
                  OMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINS
C
      IVEC(3)=0
                  ELEMENT DOF 3 TO ZERO MOTION.
C
   GLUPAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT ROD ENDS IN GLOBAL
C
   COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C
   DIRECTIONS.
C
C
   ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C
      (PU, PV, PW) JOINT 1, THEN JOINT 2.
C
   WHERE P IS FORCE.
   LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT ROD ENDS IN LOCAL.
C
C.
   COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
C
   DIRECTIONS.
C
   ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS
C
      PX1,PX2
C
   WHERE PX IS AXIAL FORCE.
   PX1(-), PX2(+) IS TENSION. PX1(+), PX2(-) IS COMPRESSION.
   STRESS TRANSFORMATION MATRIX RELATES STRESS AT ROD ENDS IN LOCAL
   COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C
   ROW URDER IN STRESS TRANSFORMATION MATRIX IS
C
      SIGMA-X1, SIGMA-X2
C
   WHERE SIGMA IS NORMAL STRESS.
C
   SX1(-), SX2(+) IS TENSION. SX1(+), SX2(--) IS COMPRESSION.
C
   DATA APRANGEMENT ON NUTMX, NUTKX, NUTLT, NUTST FOR EACH FINITE
C
   ELEMENT IS (W=M,K,LT,ST)
      WRITE (NUTWX) NAMEW, NEL, NR, NC, NAMEL, (IBLNK, I=1,5),
C
C
                     ((W(I,J),I=1,NR),J=1,NC),(IVEC(I),I=1,NC)
C
   CALLS FORMA SUPROUTINES MASIA, PAGEND, STF1A, ZZBOMB.
   DEVELOPED BY WA BENFIELD, CS BODLEY, RL WOHLEN. JANUARY 1973.
C
C
   LAST REVISION BY WA BENFIELD. MARCH 1976.
   C
   INPUT DATA READ IN THIS SUBROUTINF FROM NUTEL. IF NUTEL = 5. DATA IS
C
C
   READ FROM CAPDS.
C
      NAMEM, NAMEK, NAMELT, NAMEST
                                                   FORMAT (4(A6,4X)
C
      RO,E
                                                   FORMAT (2(5X,E10))
```

FORMAT (315,2E10) C 20 NEL, J1, J2, A1, A2 C IF (J1 .EQ. O) RETURN GO TO 20 DEFINITION OF INPUT VARIABLES. C = TYPE OF MASS MATRIX WANTED. C NAMEM = M1, DIAGONAL LUMPED. C = M2. CONSISTENT. OR 6HNUMASS, NO MASS MATRIX CALCULATED. C = 6H = TYPE OF STIFFNESS MATRIX WANTED. C NAMEK C = K1. CONSTANT AXIAL FORCE ASSUMED. OR 6HNOSTIF, NO STIFFNESS MATRIX CALCULATED. C = 6HC MAMELT = IDENTIFICATION NAME FOR LOAD TRANSFORMATION MATRICES. C OR 6HNOLOAD, NO LOAD TRANSFORMATIONS CALCULATED. = 6HNAMEST = IDENTIFICATION NAME FOR STRESS TRANSFORMATION MATRICES. C C OR 6HNOSTRS, NO STRESS TRANSFORMATIONS CALCULATED. = 6HC RC = MASS DENSITY. C = YOUNGS MODULUS OF ELASTICITY. = FINITE ELEMENT NUMBER. FOR REFERENCE ONLY, NOT USED IN C NEL C CALCULATIONS. WRITTEN ON NUTMX, ETC. C = JOINT NUMBER AT POD END 1. Jl C J2 = JOINT NUMBER AT ROD END 2. C A1 = CROSS-SECTION AREA AT ROD END 1. C = CROSS-SECTION AREA AT ROD END 1. A2 C EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED. C C I = INTEGER DATA, RIGHT ADJUSTES. F = DECIMAL POINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED. C X = CARD COLUMNS SKIPPED. C C C C SUBROUTINE ARGUMENTS (ALL INPUT) = MATRIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWS CORRESPOND C XYZ C TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT C X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ,3). C = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND **JDOF** C TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT C TRANSLATION DOFS AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT C ROTATION DOFS. SIZE(NJ,6). C = MATRIX OF JOINT FULER ANGLES (DEGREES). ROWS CORRESPOND EUL € TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE GLOPAL X,Y,Z PERMUTATION. SIZF(NJ,3). C C = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR NUTEL C THIS SUBROUTINE. IF NUTEL = 5. DATA IS READ FROM CARDS. = NUMBER OF JOINTS OR POWS IN MATRICES (XYZ), (JDOF), (EUL). C NJ C = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT NUTMX C MASS MATRICES AND IVECS ARE OUTPUT. C NUTMX MAY BE ZERO IF MASS MATRIX IS NOT FORMED. C USES FORTRAN PEAD, WRITE. = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMEN'S C NUTKX C STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION C MATRICES) AND IVECS ARE OUTPUT. C NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED. C USES FORTRAN READ, WRITE. NUTLY = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOCAL

```
LOAD TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C
            NUTLY MAY BE ZERO IF LOAD TRANSFORMATIONS ARE NOT FORMED.
C
C
            USES FORTRAN READ, WRITE.
C
   NUTST
         = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C
            STRESS TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C
            NUTST MAY BE ZERO IF STRESS TRANSFORMATIONS ARE NOT FORMED.
C
            USES FORTRAN READ, WRITE.
C
  W
          = MATRIX WORK SPACE. MIN SIZE(6,6).
C
  T
          = MATHIX WORK SPACE. MIN SIZE(6,6).
C
          = MATPIX WORK SPACE. MIN SIZE(6,6).
C
  KX
          = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
C
          = ROW DIMENSION OF JOOF IN CALLING PROGRAM.
C
  KE
          = ROW DIMENSION OF EUL IN CALLING PROGRAM.
C
          = ROW DIMENSION OF W. T. AND S IN CALLING PROGRAM. MIN=6.
C
C
      NERROR EXPLANATION
   1 = JOINT NUMBER GREATER THAN NUMBER OF JOINTS.
C
   2 = MASS MATRIX FORMED, NUTMX .LE. ZERO.
   3 = STIFFNESS MATRIX FORMED, NUTKX .LE. ZERO.
C
   4 = LT MATRIX FORMED, NUTLT .LE. ZERO.
   5 = ST MATRIX FORMED, NUTST .LE. ZERO.
 1001 FURMAT (4(A6,4X))
 1002 FORMAT (2(5X,E10.0))
 1003 FORMAT (315,4E10.0)
 2001 FORMAT (//46X 29HINPUT DATA FOR AXIAL ELEMENTS)
 2002 FORMAT (//40X 41HINPUT DATA FOR AXIAL ELEMENTS (CONTINUED))
 2003 FORMAT (/ 16X7HMASS = A6, 9X7HSTIF = A6, 9X13HLOAD TRANS = A6,
                6X15HSTRESS TRANS = A6,
              / 18X4HRO = E10.3, 9X3HE = E10.3,
              //16X7HELEMENT 13X7HJOINT 1 13X7HJOINT 2 15X4HAREA
     *
                16X4HAREA / 16X6HNUMBER 55X7HJOINT 1 13X7HJOINT 2 /1
 2004 FORMAT (1X 3120, 14X E10.3, 10X E10.3)
C.
C
   READ AND WRITE FINITE ELEMENT DATA.
      NLINE = 0
      CALL PAGEND
      WRITE (NOT, 2001)
      READ (NUTEL, 1001) NAMEM, NAMEK, NAMELT, NAMEST
      READ (NUTEL, 1002) RO, E
      WRITE (NOT, 2003) NAMEM, NAMEK, NAMELT, NAMEST, RO, E
   20 READ (NUTEL, 1003) NFL, J1, J2, A1, A2
      IF (J1 .LE. O) RETURN
      NLINE = NLINE + 1
      IF (NLINE .LE. 42) GO TO 30
      CALL PAGEND
      WRITE (NOT, 2002)
      WRITE (NOT, 2003) NAMEM, NAMEK, NAMELT, NAMEST, RO, E
      NLINE = 0
   30 WRITE (NOT,2004) NEL, J1, J2, A1, A2
                                                                  NERROR=1
      IF (J1 .GT. NJ .OR. J2 .GT. NJ ) GO TC 999
   FORM FINITE ELEMENT COORDINATE LOCATIONS, EULER ANGLES. REVADD IVEC.
      DO 42 I=1,3
```

```
CJ(I,1) = XYZ\{J1,I\}
    CJ(I,2) = XYZ(J2,I)
    EJ(I,1) = EUL(JI,I)
    EJ(I,2) = EUL(J2,I)
    IV1(I) = JDCF(J1,I)
    IV1(I+3) = JDOF(J2,I)
 FORM MASS MATRIX (W).
    IF (NAMEM .EQ. 6H
                            .CR. NAMEM .EQ. 6HNOMASS) GO TO 110
    CALL MASIA (CJ,EJ,AI,A2,RO,NAMEM,W,KCJ,KCJ,KW)
                                                                NERROR=2
    IF (NUTMX .LE. 0) GO TO 999
    WRITE (NUTMX) NAMEM, NEL, NFW, NRW, NAMEL, (IBLNK, I=1, 5),
                   ((W(I,J),I=1,NRW),J=1,NRW),(IV1(I),I=1,NRW)
FORM STIFFNESS MATRIX (W), LOCAL LOAD TRANSFORMATION MATRIX (T),
STRESS TRANSFORMATION MATRIX (S).
110 IF (NAMEK .EQ. 6H
                             .CR. NAMEK .EQ. 6HNOSTIFI GO TO 20
    CALL STF1A (CJ,EJ,A1,A2,E,NAMEK,NAMEST,W,T,S,NRST,
                 KCJ+KCJ+KW+KW+KW)
                                                                NERROR=3
    IF (NUTKX .LE. 0) GO TO 999
    WRITE (NUTKX) NAMEK, NEL, NRW, NRW, NAMEL, (IBLNK, I=1,5),
                   \{(W(I,J),I=1,NRW),J=1,NRW\},(IVI(I),I=1,NRW)\}
    IF (NAMELT .EQ. 6H
                              .OR. NAMELT .EQ. 6HNOLOAD) GO TO 115
                                                              · NERROR=4
    IF (NUTLT .LE. 0) GC TO 999
    WRITE (NUTLT) NAMELT, NEL, NRLT, NRW, NAMEL, (IBLNK, I=1,5),
                   ((T(I,J),I=1,NRLT),J=1,NRW),(IV1(I),I=1,NRW)
115 IF (NAMEST .EQ. 6H
                              .OR. NAMEST .EQ. 6HNOSTRS) GO TO 20
                                                                NERROR≈5
    IF (NUTST .LE. 0) GG TO 999
   WRITE (NUTST) NAMEST, NEL, NRST, NRW, NAMEL, (IBLNK, I=1,5),
                   ((S(I,J),I=1,NRST),J=1,NRW),(IV1(I),I=1,NRW)
   GO TO 20
999 CALL ZZBOME (6HAXIAL ,NERROR)
   END
```

```
SUPPOUTING BLAI (RL 22,KZ)
      DIMENSION 2(KZ:1)
 SUBROUTINE TO CALCULATE FINITE ELEMENT...
C
     FUCKLING MATRIX
   FOR AN AXIAL RCD ELEMENT WITH UNRESTRAINED EQUIDARIES.
   BUCKLING MATRIX IS BASED ON UNIT AXIAL LOAD.
   BUCKLING MATRIX IS IN LOCAL COORDINATE SYSTEM.
C
   THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE IN THE X-Z PLANE
   WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
   LOCAL COORDINATE GREEK IS
C
      DZ1,DZ2
   WHERE DZ IS TRANSLATION.
C
   DEVELOPED BY RL WOHLEN. AUGUST 1973.
C
   LAST PEVISION BY RL WOHLEN. SEPTEMBER 1973.
C
      SUBROUTINE ARGUMENTS
C
   RL = INPUT POD LENGTH.
C
   Z = OUTPUT EUCKLING MATRIX. SIZE(2,2).
   KZ = INPUT RUW DIMENSION OF Z IN CALLING PROGRAM, MIN=2.
      C = 1./RL
      Z(1,1) = C
      Z(1,2) =-C
      Z(2,1) = -C
      Z(2,2) = C
      RETURN
      END
```

```
SUBROUTINE 81A2
                        (R1.,Z,KZ)
      DIMENSION Z(KZ,1)
  SUBROUTING TO CALCULATE FINITE ELEMENT ...
      BUCKLING MATRIX
  FOR A BEAM ELEMENT WITH UNRESTRAINED BOUNDARIES.
  BUCKLING MATRIX IS BASED ON UNIT AXIAL LOAD.
  BUCKLING MATRIX IS IN LOCAL COORDINATE SYSTEM.
  THE LOCAL COORDINATE SYSTEM ASSUMES THE BEAM TO LIE IN THE X-2 PLANE.
C
  WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AX1S.
C
C
  LOCAL COORDINATE ORDER IS
C
      DZ1,DZ2,TY1,TY2
C
  WHERE DZ IS TRANSLATION AND TY IS ROTATION.
  DEVELOPED BY RL WCHLEN. AUGUST 1973.
C
C
  LAST REVISION BY RL WOHLEN. SEPTEMBER 1-73.
ũ
C
      SUBROUTINE ARGUMENTS
C
  RL = INPUT RCD LENGT't.
  Z = CUTPUT EUCKLING MATRIX. SIZE(4,4).
  KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=4.
      C1 = 6./(5.*RL)
      C2 = .1
      C3 = (2.*RL)/15.
      2(1,1) = C1
      Z(1,2) =-C1
      Z(1,3) = -C2
      Z(1,4) = -C2
      Z(2,2) = C1
      Z(2,3) = C2
      2(2,4) = 62
      Z(3,3) = C3
      Z(3,4) = -RL/30.
      Z(4,4) = C3
      DC 16 I=1,4
      DG 10 J=1,4
   10 Z(J,I) = Z(I,J)
C
      RETURN
```

END

```
SUBROU', INE BAR
                        (XYZ, JDCF, EUL, NUTEL, NJ,
                         NUTHY, NUTKX, NUTRX, NUTLT, NUTST,
                         W.T.S.KX.KJ.KE.KW)
     DIMENSION XYZ(KX,1),JDCF(KJ,1),EUL(KE,1),W(KW,1),T(KW,1),S(KW,1)
     DIMENSION CJ(3,3), EJ(3,2), IVI(12), TR(12,12), TD(24,24)
     DIMENSION KODEK(4), KODEB(2), IFPIN(4), IV2(4)
     DATA NAMEL / 6HEAP
     DATA NPW, NRLT/12, 12/, IBLNK/6H
                                          /, KCJ/3/, KTR/12/,KTD/24/
      DATA NIT, NOT/5,6/
C
   SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT ...
C
     MASS MATRICES AND IVECS (CN NUTMX),
C
C
      STIFFNESS MATRICES (SAME AS GLOBAL LOAD TRANSFORMATION MATRICES)
C
      AND IVECS (ON NUTKX),
      UNIT LOAD BUCKLING MATRICES AND IVECS (ON NUTBX).
C
C
      LOCAL LOAD TRANSFORMATION MATRICES AND IVECS (ON NUTLT),
      STRESS TRANSFORMATION MATRICES AND IVECS (ON NUTST)
C
  FOR COMPINED AXIAL-TORSTON-BENDING BAR ELEMENTS.
C
  MASS, STIFFMESS, BUCKLING MATRICES ARE IN GLOBAL COORDINATE
C
C
   DIRECTIONS.
C
   GLOBAL COORDINATE ORDER FOR EACH ELEMENT IS
C
      (U,V,K,P,Q,R) JOINT 1, THEN JOINT 2
C
   WHERE U, V, W ARE TRANSLATIONS AND P,Q,R ARE ROTATIONS.
C
   IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
      IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
C
      IVEC(3)=0
                  OMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINS
C
                  ELEMENT DOF 3 TO ZERO MOTION.
C
C
  GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT BAR ENDS IN GLOBAL
C
  CCORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C
   DIRECTIONS.
  ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C
C
      (PU, PV, PW, MP, MQ, MR) JOINT 1, THEN JOINT 2.
€
  WHERE P IS FORCE AND M IS MOMENT.
  LOCAL LOAD TPANSFORMATION MATRIX RELATES LOADS AT BAR ENDS IN LOCAL
C
C
   COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
   ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS
      PX1,PX2,MX1,MX2,FY1,PY2,MZ1,MZ2,PZ1,PZ2,MY1,MY2
C
\boldsymbol{c}
   WHERE P IS FORCE AND M IS MOMENT.
C
   STRESS TRANSFORMATION MATRIX RELATES STRESS AT BAR ENDS IN LOCAL
   COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C
   ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C
                        MX1*R1/TJ1, MX2*R2/TJ2,
      PXI/AI,PX2/A2,
C
      PY1/A1, PY2/A2, MZ1*CY1/BIZ1, MZ2*CY2/RIZ2,
C
      PZ1/A1,PZ2/A2,MY1*CZ1/B1Y1,MY2*CZ2/BIY2
C
   WHERE P IS FORCE AND M IS MOMENT.
   DATA ARRANGEMENT ON NUTMX, NUTKX, NUTEX, NUTLT, NUTST FOR EACH
C
   FINITE ELEMENT IS (W=M,K,B,LT,ST)
C
      WRITE (NUTWX) NAMEW, NEL, NR, NC, NAMEL, (IBLNK, I=1,5),
                    ((W(I,J),I=1,NR),J=1,NC),(IVEC(I),I=1,NC)
C
   CALLS FORMA SUBROUTINES BUCIE, MASIE, PAGEHD, STF18, ZZBOMB.
   DEVELOPED BY WA BENFIELD, CS BODLEY, RL WOHLEN. FEBRUARY 1973.
C
   LAST REVISION BY RL WOHLEN.
                                 APRIL 1976.
C
C
   ******************
```

INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = 5, DATA IS

C

```
C
   READ FROM CAPDS.
€
      NAMEM, NAMEK, NAMELT, NAMEST, NAMEE,
                                                    FORMAT (5(A6,4X),
C
       (KODEK(I), I=1,4), (KODEB(I), I=1,2)
                                                     A1,A1,A2,A2,4X,A2,A2}
                                                    FORMAT (3(5X,E10))
C
      RO.E.G
C
   20 NéL, J1, J2, JREF, A1, PI1, TJ1, BIZ1, BIY1, SF,
C
      IFPY1, IFP 21, IFPY2, IFP 22, IFTAPR
                                                    FORMAT (415,5E10,E5,5A1)
C
      IF (J1 .FC. O) RETURN
C
                                                    FORMAT (20X,5E10)
      IF (IFTAPK .EO. 1HT) A2,P12,TJ2,B1Z2,B1Y2
C
   30 IF (NAMEST .EQ. 6H
                                .OR. NAMEST .EQ. 6HNOSTRS) GO TO 20
C
                                                     FORMAT (20X,6E10)
      R1,CY1,CZ1,R2,CY2,CZ2
C
      GB TD 26
C
C
   INPUT DATA REQUIREMENTS
C
                       AXIAL
                                  TORSION
                                             BENDING
                                                             BENDING
C
                       ALCNG
                                    ABOUT
                                              APOUT
                                                              ABOUT
C
                                  LCCAL X
                                                             LOCAL Y
                       LCCAL X
                                             LOCAL Z
ε
C
                       A,RC
                                  PI.RC
                                             A.RO
                                                             A,RO
  MASS
€
   STIF, LOAD TRANS
                                             PIZ, A, SF, E, G
                                                             EIY, A, SF, E, G
                       A,E
                                   TJ,G
   EUCKLING
                                  NONE
C
                       NCNE
                                             NONE
                                                             NONE
                       SEE STIF
C
   STRESS TRANS
                                   STIF+R
                                             STIF+CY
                                                             STIF+CZ
   FOR NO SHEAR DEFORMATION IN BENDING, SET ANY OF A(NOT IF AXIAL USED).
C
   SF, OF GINET IF TERSION IS USED) TO ZEPO. IF BENDING STRESS
C
C
   TRANSFORMATION IS WANTED, A MUST NOT BE ZERO.
C
C
   DEFINITION OF INPUT VARIABLES.
C
   NAMEM = TYPE OF MASS MATRIX WANTED.
            = M1, DIAGONAL LUMPED.
C
C
            = M2, CONSISTENT.
C
                        CR 6HNOMASS, NO MASS MATRIX CALCULATED.
C
         = TYPE OF STIFFNESS MATRIX WANTED.
   NAMEK
             = K1, CONSTANT FORCE FOR AXIAL, CONSTANT TORQUE FOR TORSION,
C
C
                   CONSTANT SHEAR AND LINEAR MOMENT FOR BENDING.
C
                        OF 64MOSTIF, NO STIFFNESS MATRIX CALCULATED.
            = 64
   NAMELT = IDENTIFICATION NAME FOR LOAD TRANSFORMATION MATRICES.
C
                        OR SENCEDAD, NO LOAD TRANSFORMATIONS CALCULATED.
C
            = 6H
C
   NAMEST = IDENTIFICATION NAME FOR STRESS TRANSFORMATION MATRICES.
C
                        OR SHOUSTRS, NO STRESS TRANSFORMATIONS CALCULATED.
C
          = TYPE OF EUCKLING MATRIX WANTED.
   NAMES
C
            = EI, AXIAL RCO.
C
            = BZ, BEAN.
            = 6H
                        CE SHNOBUCK, NO BUCKLING MATRIX CALCULATED.
C
          = OPTION CODE FOR AXIAL, TORSION, BENDING Z, BENDING Y LOCAL
C
   KODEK
C
            STIFFNESS. IF BLANK, BLL FOUR ARE CALCULATED. SIZE(4).
C
            KODEK(1)=A , LOCAL STIF MATRIX IS CALCULATED FOR AXIAL
C
                           (ALONG LOCAL X-AXIS).
C
            KODEK(2)=T , LOCAL STIF MATRIX IS CALCULATED FOR TORSION
€
                           TAPOUT LOCAL X-AXISE
C
            KODEK(3)=62, LOCAL STIF MATRIX IS CALCULATED FOR BENDING
                           (AFOUT LOCAL Z-AXIS).
C
C
             KODEK(4)=FY, LOCAL STIF MATRIX IS CALCULATED FOR BENDING
                           IMBOUT LOCAL Y-AXIS).
£
C
   KODER = OPTION CODE FOR EUCKLING IN LOCAL Y OR Z DIRECTION.
C
             IF PLANK, BOTH ARE CALCULATED. SIZE(2).
             KUDER(1)=BY, LOCAL EUCKLING MATRIX IS CALCULATED FOR
C
```

```
DEFLECTION IN LOCAL Y CIRECTION.
C
C
            KODEE(2)=EZ, LOCAL PUCKLING MATRIX IS CALCULATED FOR
C
                         DEFLECTION IN LOCAL 2 DIRECTION.
C
   RO.
          = MASS DENSITY.
C
          = YOUNGS MODULUS OF ELASTICITY.
   E
C
   G
          = SHEAR MODULUS OF FLASTICITY.
C
          = FINITE ELEMENT NUMBER. FOR PEFERENCE ONLY. NOT USED IN
   NEL
C
            CALCULATIONS. WRITTEN ON NUTMX, ETC.
C
   J1
          = JOINT NUMBER AT BAR END 1. LOCAL X-AXIS ORIGINATES AT J1.
C
          = JGINT NUMBER AT BAR END 2. LOCAL X-AXIS GOES FROM J1 TO J2.
   J2
          = REFERENCE POINT. LOCAL Z-AXIS IS DEFINED BY VECTOR (J1,J2)
C
   JREF
C
            CPUSSED INTO VECTOR (J1, JREF). LOCAL Y-AXIS LIES IN XY PLANE
            DEFINED EY J1,J2, JREF.
C
C
   Al
          CROSS-SECTION AREA AT BAR END 1.
C
          = SAME AS AT AT BAR END 2.
   A2
C
          = CROSS-SECTION POLAR AREA MOMENT OF INERTIA FOR MASS
   PII
C
            CALCULATIONS AT EAR END 1.
C
   PIZ
          = SAME AS PII AT EAR END 2.
          = CRESS-SECTION SAINT VENANTS TORSION CONSTANT (J) IN JG FOR
C
   TJ1
C
            TORSION STIFFNESS AT EAR END 1.
C
   TJ2
          = SAME AS TJ1 AT BAR END 2.
C
   SIZ1
          = CROSS-SECTION AREA MOMENT OF INERTIA ABOUT LOCAL Z-AXIS
C
            (FO? BENDING) AT PAR END 1.
          = SAME AS FIZI AT EAR END 2.
C
   BIZ2
          = CROSS-SECTION AREA MOMENT OF INERTIA ABOUT LOCAL Y-AXIS
C
   EIYI
C
            (FOR FENDING) AT BAR END 1.
C
          = SAME AS FIYE AT EAR END 2.
   BIY2
C
          = SHAPE FACTOR (K) FOR SHEAR IN KAG.
   SF
            USE SF=0.0 FOR NO SHEAR DEFORMATION IN BENDING.
C
C
            SF=1.0 FOR A SOLID CIRCULAR CYLINDER.
C
            SF=.5 FOR A THIN WALLED CIRCULAR CYLINDER.
C
   IFPY]
          = PIN JOINT OPTION FOR LOCAL COORDINATE THETA Y AT BAR END 1.
C
            = 1H , MOMENT JOINT.
C
            = 1PP, PIN JOINT.
C
   IFPY2
          = SAME AS IFPY1 AT EAR END 2.
C
   IFP21
          = PIN JOINT OPTION FOR LOCAL COORDINATE THETA Z AT BAR END 1.
C
            = 1H . MOMENT JOINT.
C
            = 1 AP, PIN JCINT.
C
          = SAME AS IFPZ1 AT EAR END 2.
   IFPZ2
   IFTAPR = OPTION FOR TAPERED EAR.
C.
            = 1H . CONSTANT SECTION PROPERTIES.
C
            = 1HT, LINEAR TAPER SECTION PROPERTIES.
C
î
          = DISTANCE FROM LOCAL X-AXIS TO CUTER FIBER FOR TORSION
   R1
C
            STRESS CALCULATION AT BAR END 1.
C
   R2
          = SAME AS RI AT BAR END 2.
         .= DISTANCE FROM LOCAL XZ PLANE TO OUTER FIBER FOR BENDING
C
   CYI
C
            STRESS CALCULATION AT BAR END 1. LOCAL Y DIRECTION.
C
   CY2
          = SAME AS CY1 AT BAR END 2.
          = DISTANCE FROM LOCAL XY PLANE TO OUTER FIBER FOR BENDING
C
   CZ1
C
            STRESS CALCULATION AT BAR END 1. LOCAL Z DIRECTION.
C
   CZ2
          = SAME AS CZ1 AT BAR END 2.
C
   EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C
      I = INTEGER DATA, RIGHT ADJUSTED.
C
      E = DECIMAL POINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED.
```

```
X = CARD COLUMNS SKIPPED.
   C
C
      SUBROUTINE ARGUMENTS (ALL INPUT)
C
          = MATRIX OF JOINT GLOBAL X.Y.Z LOCATIONS. ROWS CORRESPOND
   XYZ
C
            TO JOINT NUMBERS. CTLUMNS 1,2,3 CORRESPOND TO THE JOINT
C
            X.Y.Z LOCATIONS RES ECTIVELY. SIZE(NJ.3).
C.
          = MATRIX OF JOINT GRAPTAL DEGREES OF FREEDOM. ROWS CORRESPOND
   JDOF
C
            TO JOINT NUMBER JA PLUMNS 1,2,3 CORRESPOND TO THE JOINT
            TRANSLATION DOES AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
C
C
            ROTATION DOFS. SXZE(NJ.6).
C
          = MATRIX OF JOINT EVILER ANGLES (DEGREES). ROWS CORRESPOND
   EUL
           TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
C
            GLOBAL X,Y,Z PERMUTATION. SIZE(NJ,3).
C
          = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
C
   NUTEL
            THIS SUBROUTINE. IF NUTEL = 5, DATA IS READ FROM CARDS.
          = NUMBER OF JOINTS RE ROWS IN MATRICES (XYZ), (JDOF), (EUL).
C
   NJ
C
   NUTMX
         = LOGICAL NUMBER OF I TILITY TAPE ON WHICH ELEMENT
            MASS MATPICES AND IVECS ARE OUTPUT.
            MUTHX MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C
C
            USES FORTRAN READ, WRITE.
   NUTKX = LOGICAL NUMBER 'OF UTILITY TAPE ON WHICH ELEMENT
C
C
            STIFFNESS MATRICES ASAME AS GLOBAL LOADS TRANSFORMATION
C
            MATRICES) AND IVECS ARE OUTPUT.
            NUTKX MAY BE ZERD IF STIFFNESS MATRIX IS NOT FORMED.
C
C
            USES FORTRAN READ, WRITE.
C
   NUTBX = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT UNIT LOAD
C
            BUCKLING MATRICES AND IVECS ARE OUTPUT.
C
            NUTRX MAY BE ZER! IF BUCKLING MATRIX IS NOT FORMED.
C
            USES FORTRAN REAL, WRITE.
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOCAL
€
   NUTLT
            LOAD TRANSFORMATION MATRICES AND IVECS ARE CUTPUT.
C
            NUTLY MAY BE ZERO IF LOAD T' ANSFORMATIONS ARE NOT FORMED.
C
C
            USES FORTRAN READ. WRITE.
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C
   NUTST
C
            STRESS TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
            NUTST MAY BE ZERO IF STRESS TRANSFORMATIONS ARE NOT FORMED.
C
C
            USES FORTRAN READ, WRITE.
C
          = MATRIX WORK SPACE. MIN SIZE(12,12).
          = MATRIX WORK SPACE. MIN SIZE(12:12:.
C
   T
          = MATPIX WORK SPACE. MIN SIZE(17,12).
C
   5
C
   ΚX
          = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
          = ROW DIMENSION OF JOOF IN C. LLING PROGRAM.
C
   KJ
          = ROW DIMENSION OF EUL IN LALLING PROGRAM.
C
   ΚE
          = ROW DIMENSION OF W. T. AND S IN CALLING PROGRAM. MIN=12.
C
   KW
C
     NERROR EXPLANATION
C
   1 = JOINT NUMBER GREATER TEAN NUMBER OF JOINTS.
   2 = STIFFNESS MATRIX FORMED, NUTKX .LE. ZERC.
   3 = LOAD TRANSFORMATION MATRIX FORMED, NUTLT .LE. ZERO.
   4 = STRESS TRANSFORMATION MATRIX FORMED, MUTST .LE. ZERO.
   5 = MASS MATRIX FORMED, NUTMX .LC. ZERO.
   6 = BUCKLING MATRIX FORMED, NIVER .LE. ZERO.
 1001 FORMAT (5(A6,4X),A1,A1 A2,A2, 4X A2,A2)
```

```
1002 FORMAT (3(5X,E10.0))
 1003 FORMAT (415,5E10.0,E5.0,5A1)
 1004 FORMAT (20x,6E1G.0)
2001 FORMAT (//46X 27HINPUT DATA FOR BAR ELEMENTS)
 2002 FORMAT (//40x 39HINPUT DATA FOR BAR ELEMENTS (CONTINUED))
 2003 FORMAT ( 45X,8HKODEK = A1,A1,A2,A2, 4X 8HRODEB = A2,A2,
  C- *
              / 10x7HMASS = A6, 6x7HSTIF = A6, 6x13HLOAD TRANS = A6,
                3X15HSTRESS TRANS = A6. 3X11HBUCKLING = A6.
              / 12X4HRC = E10.3, 6X3HE = E10.3, 80X7HI I I I,
              / 32X3HG = E10.3, 80X7HF F F F,
              / 125X7HP P P P,
              / 1X7HELEMENT 2X5HJ0INT
                                          2X5HJOINT
                                                      3X3HREF 5X4HAREA
     *
                 7X5HPOLAR 5X7HTCRSION 3X9HZ BENDING 2X9HY BENDING
                 2X5HSHEAR 3X6HSTRESS 5X6HSTRESS 5X6HSTRESS 3X7HY Z Y Z
              / 1X6HNUMBER 5X1H1 6X1H2 4X5HPOINT
                 14X 7HINERTIA 5X5HCONST 5X7HINERTIA
                 4X7HINERTIA 3X6HFACTOR 5X1HR 9X2HCY 9X2HCZ 5X7H1 1 2 2/1
 2004 FORMAT (1X 15, 18, 217, 1X 5E11.3, F7.3, 3E11.3, 4(1XA1))
2005 FORMAT (29X,5E11.3,7X,3E11.3)
C.
C
  READ AND WRITE FINITE ELEMENT DATA.
      R1 = 0.0
      CY1 = 0.0
      CZ1 = 0.0
      NLINE = 0
      CALL PAGEND
      WRITE (NOT, 2001)
      READ (NUTEL, 1001) NAMEM, RAMEK, NAMELT, NAMEST, NAMEB,
                         (KODEK(I),I=1,4),(KODEB(I),I=1,2)
      READ (NUTEL, 1002) RU, E, G
      WRITE (NOT, 2003) (KCDEK(I), I=1,4), (KCDEB(I), I=1,2),
                        NAMEM, NAMEK, NAMELT : NAMEST, NAMEB, RO, F, G
   20 READ (NUTEL, 1003) NEL, J1, J2, JREF, A1, P11, TJ1, B121, B1Y1, SF,
                         IFP IN , IFTAPR
      IF (J1 .LE. O) RETURN
      IF (IFTAPR .EQ. 1HT) READ (NUTEL, 1004) A2, P12, TJ2, BIZ2, BIY2
                               .UR. NAMEST .EQ. 6HNOSTRS) GO TO 25
      IF (NAMEST .EQ. 6H
      READ (NUTFL, 1004) R1, CY1, CZ1, R2, CY2, CZ2
   25 NLINE = NLINE + 1
      IF (IFTAPR .EQ. 1HT) MLINF=NLINE+1
      IF (NLINE .LE. 42) GO TO 30
      CALL PAGEND
      WRITE (NOT, 2002)
      WRITE (NOT, 2003) (KCD EK(1), I=1,4), (KCDER(1), I=1,2),
                        NAMEM, NAMEK, NAMELT, NAMEST, NAMEB, RO, E, G
      NLINE = C
   30 WRITE (NOT,2004) NEL, JJ, J2, JREF, Al, PII, TJI, BIZI, BIYI, SF,
                        R1,CY,,CZ1,IFPIN
                                                                   NERROR=1
      IF (J1 .GT. NJ .CR. J2 .GT. NJ .CR. JREF .GT. NJ) GO TO 999
      IF (IFTAPR .F). 1HT) WRITE (NOT,2005) A2,PI2,TJ2,BIZ2,BIY2,R2,
                                              CY2,CZ2
C
   FORM FINITE FLEMENT COORDINATE LOCATIONS, EULER ANGLES, REVADD IVEC.
      DC 42 J=1.3
```

```
CJ(I,1) = XYZ(J1,I)
      CJ(I,2) = XYZ(A2,I)
      CJ(I,3) = XYZ(JREF,I)
      EJ(I,I) = EUL(JI,I)
   42 EJ(1,2) = EUL(J2,I)
      DO 44 I=1,6
      IVI(I)
              = JDOF(J1.I)
   44 \text{ IVI}(I+6) = JD0F(J2.I)
C
  FORM DATA FOR UNIFORM ELEMENT.
      IF (IFTAPR .EQ. 1HT) GO TO 50
      A2 = A1
      P12 = PI1
      TJ2 = TJ1
      RIZ2 = RIZ1
      BIY2 = BIY1
      R2 = R1
      CY2 = CY1
      CZ2 = CZ1
C
  FORM PINING IVEC.
   50 \text{ NPIN} = 0
      DC 55 I=1.4
      IF (IFPIN(I) .NE. 1HP) GO TO 55
      NPIN = NPIN + 1
      IF (I \cdot EQ \cdot 1) IV2(NPIN) = 11
      IF (I .EQ. 2) IV2(NPIN) = 7
      IF (I .EQ. 3) IV2(NPIN) = 12
      IF (I . EQ. 4) 1V2(NPIN) = 8
   55 CONTINUE
C
  FORM STIFFNESS MATRIX (W), LOCAL LOAD TRANSFORMATION MATRIX (T).
  STRESS TRANSFORMATION MATRIX (S).
                                .OR. NAMEK .EQ. 6HNOSTIF) GO TO 110
  100 IF (NAMEK .EQ. 6H
      CALL STF1B
                   (CJ,EJ,KODEK,A1,A2,TJ1,TJ2,BIZ1,BIZ2,BIY1,BIY2,R1,R2,
     *
                    CY1, CY2, CZ1, CZ2, SF, E, G, NAMEK, NAMEST, W, T, S, NRST,
     *
                    KCJ,KCJ,KW,KW,KW)
C
   PIN STIFFNESS MATRIX.
      IF (NPIN .EQ. 0) GO TO 105
      CALL DCTSIB (CJ,EJ,W,KCJ,KCJ,KW)
      CALL TRANS
                  (W,TR,NRW,NRW,KW,KTR)
      CALL MULTA
                   (T,TR,NRLT,NRW,NRW,KW,KTR)
      CALL SRED3
                   (T,IV2,T,TD,NRW,NPIN,1,KW)
      CALL MULTA
                   (TD, W, NRW, NRW, NRW, KTD, KW)
      CALL MULTA
                   (TR,TD,NRW,NRW,NRW,KTR,KTD)
      CALL MULTA
                   (T,W,NRLT,NRW,NRW,KW,KW)
      CALL ATXRAI (W,T,NRW,NRW,KW,KW)
                                .OR. NAMEST .EQ. 6HNOSTRS) GC TO 105
      IF (NAMEST .EQ. 6H
      CALL MULTA (S.TR.NRST, NRW, NRW, KW, KTR)
  105
                                                                    NERROR= 2.
      IF (NUTKX .LE. 0) GO TO 999
      WRITE (NUTKX) NAMEK, NEL, NRW, NRW, NAMEL, (IBLNK, I=1, 5),
                     ((W(I,J),I=1,NRW),J=1,NRW),(IV1(I),I:1,NRW)
      IF (NAMELT .EQ. 6H
                                 .OR. NAMELT .EQ. 6HNOLOAD) GO TO 115
```

```
NERROR=3
```

```
IF (NUTLT .LE. 0) GO TO 999
     WRITE (NUTLT) NAMELT, NFL, NRLT, NRW, NAMEL, (IBLNK, I=1,5),
                    ((T(I,J), I=1, NRLT), J=1, NRW), (IV1(I), I=1, NRW)
 115 IF (NAMEST .EQ. 6H
                                .OR. NAMEST .EQ. 6HNOSTRS) GO TO 110
                                                                  NERROR=4
      IF (NUTST .LE. 0) GO TO 999
     WRITE (NUTST) NAMEST, NEL, NEST, NEW, NAMEL, (IBLNK, I=1,5),
                    ((S(I,J),I=1,NRST),J=1,NRW),(IV1(I),I=1,NRW)
  FORM MASS MATRIX (W).
  110 IF (NAMEM .EQ. 6H
                              .0% NAMEM .EQ. 6HNOMASS) GO TO 140
     CALL MASIB (CJ,EJ,A1,A2,PII,PI2,RO,NAMEM,W,T,KCJ,KCJ,KW,KW)
  PIN MASS MATRIX.
   F IF (NPIN .GT. 0) CALL BTABA (W.TR.NRW.NRW.KW.KTR)
                                                                  NERROR=5
      IF (NUTHX .LE. 0) GO TO 999
     WRITE (NUTMX) NAMEM, NEL, NRW, NRW, NAMEL, (IBLNK, I=1, 5),
                    ((W(I,J),I=1,NRW),J=1,NRW),(IV1(I),I=1,NRW)
C
  FORM UNIT LOAD BUCKLING MATRIX (W).
  140 IF (NAMER .EQ. 6H
                              .CR. NAMEB .EQ. 6HNOBUCK) GD TO 20
      CALL BUCIB (CJ.EJ.KODEB.NAMEB.W.S.KCJ.KCJ.KW.KW)
                                                                  NERROR=6
      IF (NUTPX .LE. 0) GO TO 999
     WRITE (NUTBX) NAMEB, NEL, NRW, NRW, NAMEL, (IBLNK, I=1,5),
                    ((W(I,J),I=1,NRW),J=1,NRW),(IV1(I),I=1,NRW)
     GD TO 20
  999 CALL ZZBOMB (6HBAR ,NERROR)
     END
```

```
SUBROUTINE BUCIB (CJ,EJ,KODER,NAMER,Z,W,KCJ,KEJ,KZ,KW)
      DIMENSION CJ(KCJ,1), EJ(KEJ,1), KODEB(1), Z(KZ,1), W(KW,1)
C
   SUBROUTINE TO CALCULATE FINITE ELEMENT ...
      BUCKLING MATRIX
   FOR A COMBINED AXIAL-TORSION-BENDING BAR ELEMENT WITH UNRESTRAINED
   BOUNDARIES.
   BUCKLING MATRIX IS BASED ON UNIT AXIAL LOAD.
   BUCKLING MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C
   GLOBAL COORDINATE ORDER IS
C
      (U,V,W,P,Q,R) JOINT 1, THEN JOINT 2
   WHERE U,V,W ARE TRANSLATIONS AND P,Q,R ARE ROTATIONS.
C
   EULER ANGLE CONVENTION IS GLUBAL X,Y,Z PERMUTATION.
   CALLS FORMA SUBROUTINES BIAI, BIA2, BTABA, DCGS1B, ZZBOMB.
   DEVELOPED BY RL WOHLEN. AUGUST 1973.
   LAST REVISION BY WA BENFIELD. MARCH 1976.
C
      SUBROUTINE ARGUMENTS
C
                   MATRIX OF GLOBAL X,Y,Z COORDINATES AT BAR JOINTS.
C
   CJ
          = INPUT
                   ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C
C
                   COLS 1,2 COPRESPOND TO JOINTS 1,2. COL 3 CORRESPONDS
C
                   TO REFERENCE POINT TO DEFINE LOCAL XY PLANE. SIZE(3,3).
C
          = INPUT
                   MATRIX OF EULER ANGLES (DEGREES) AT BAR JOINTS.
   EJ
C
                   ROWS 1,2,3 CORRESPOND TO GLOPAL X,Y,Z PERMUTATION.
                   COLS 1,2 CORFESPOND TO JOINTS 1,2. SIZE(3,2).
C
C
   KODEB = INPUT
                   OPTION CODE FOR LOCAL Y, LOCAL 2 BUCKLING.
                   IF BLANK, BOTH ARE CALCULATED. SIZE(2).
C
C
                   KODEB(1)=BY, LOCAL BUCKLING MATRIX IS CALCULATED
C
                                 FOR LOCAL Y DIRECTION.
                   KODEE(2)=6Z, LOCAL BUCKLING MATRIX IS CALCULATED
C
                                 FOR LOCAL Z DIRECTION.
                   TYPE OF BUCKLING MATRIX WANTED.
   NAMEB = INPUT
C
C
                   =P1, AXIAL RCD.
C
                   =62, BEAM.
          = OUTPUT BUCKLING MATRIX. SIZE(12,12).
C
   Z
                   WORK SPACE MATRIX. SIZE(12,12).
C
          = INPUT
C
   KCJ
          = INPUT
                   ROW DIMENSION OF CJ IN CALLING PROGRAM.
C
   KEJ
          = INPUT
                   ROW DIMENSION OF EJ IN CALLING PROGRAM.
C
          = INPUT
                   ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=12.
   ΚZ
C
          = INPUT ROW DIMENSION OF W IN CALLING PROGRAM. MIN=12.
   KW
C
      NERROR EXPLANATION
C
C
   1 = DIMENSION SIZE EXCEEDED.
   2 = IMPROPERLY DEFINED NAMEB.
                                                              NERROR=1
      IF (KZ .LT. 12 .OR. KW .LT. 12) GG TO 999
      DO 5 J=1,12
      DO 5 I=1,12
    5 Z(I_*J) = 0.0
      RL = SQPT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
                                      + (CJ(3,2)-CJ(3,1))**2)
      KODERY = 1
      KODERZ = 1
```

IF (KODEB(1).EQ.2H .AMD. KODEB(2).EQ.2H ) GC TO 10

```
IF (KODEP(1) .NE. 2HBY) KODEBY = 0
       IF (KODEB(2) .NE. 2HBZ) KCDEBZ = 0
10 1F (NAMER .EQ. 6HB1 ) GO TO '10
                             ) GO TO 120
       IF (NAMEB .EQ. 6HB2
                                                               NERROR=2
       GO TO 999
   110 IF (KODERY .EQ. 1) CALL B1A1 (RL,Z(5,5),KZ)
       IF (KODEBZ .EQ. 1) CALL BIA1 (RL,Z(9,9),KZ)
       GD TD 300
C
   120 IF (KODERY .EQ. 1) CALL B1A2 (RL,Z(5,5),KZ)
       DO 125 J=7.8
       DO 125 I=5,6
       Z(1,J) = -Z(1,J)
   125 Z(J,I) = -Z(J,I)
       IF (KODEBZ .EQ. 1) CALL B1A2 (RL,2(9,9),KZ)
 ·C
   300 CALL DCOS1B (CJ,EJ,W,KCJ,KEJ,KW)
       CALL PTABA (2,W, 12,12, KZ,KW)
       RETURN
   999 CALL ZZBOMB (6HBUC1B ,NERROR)
       END
```

DIMENSION CJ(KCJ,1), EJ(KEJ,1), Z(KZ,1) DIMENSION P(3), T(3,3)SUBROUTINE TO CALCULATE FINITE ELEMENT ... C DIRECTION COSINE MATRIX FOR AN AXIAL ROD ELEMENT. C THE DIRECTION COSINE MATRIX RELATES LOCAL COORDINATE DISPLACEMENTS TO GLOBAL COORDINATE DISPLACEMENTS. THE LOCAL COURDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS. ROW ORDER (LECAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS C € DX1,DX2 C WHERE DX IS TRANSLATION. COLUMN ORDER (GLOBAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS (U, V, W) JOINT 1, THEN JOINT 2. C C WHERE U, V, W ARE TRANSLATIONS. C EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION. CALLS FORMA SUBROUTINES EULER, MULTB, ZZBOMB. DEVELOPED BY RL WOHLEN. SEPTEMBER 1972. C LAST REVISION BY WA BENFIELD. MARCH 1976. C C SUBROUTINE ARGUMENTS C = INPUT MATRIX OF GLOBAL X,Y,Z COORDINATES AT ROD JOINTS. C ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES. C COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2). C MATRIX OF EULER ANGLES (DEGREES) AT ROD JOINTS. EJ = INP\_UT ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION. C CCLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2). Ç C = OUTPUT DIRECTION COSINE MATRIX. SIZE(2,6). Z C POW DIMENSION OF CJ IN CALLING PROGRAM. KCJ = INPUT ROW DIMENSION OF EJ IN CALLING PROGRAM. C KEJ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2. C ΚZ = INPUT C NEPROR EXPLANATION C 1 = DIMENSION SIZE LESS THAN 2. C NERROR = 1IF (KZ .LT. 2) GD TD 999 PX = CJ(1,2)-CJ(1,1)PY = CJ(2,2)-CJ(2,1)PZ = CJ(3,2)-CJ(3,1)PL = SQRT(PX\*\*2 + PY\*\*2 + PZ\*\*2)P(1) = PX/PLP(2) = PY/PLP(3) = PZ/PLDO 10 I=1,2 DO 10 J=1,6 10 Z(I,J) = 0.0CALL EULEP (FJ(1,1), T,3) CALL MULTB (P,T, 1,3,3, 1,3) DC 22 J=1,3 22 Z(1,J) = T(1,J)CALL EULER (EJ(1,2),T,3) CALL MULTB (P,T, 1,3,3, 1,3)

SUBROUTINE DCOSIA (CJ,EJ,Z,KCJ,KEJ,KZ)

DO 24 J=1,3
24 Z(2,J+3) = T(1,J)
RETURN
C
999 CALL ZZBOMB (6HDCOS1A,NERROR)
END

SUBROUTINE DEOSIB (CJ,EJ,Z,KCJ,KEJ,KZ) DIMENSION CJ(KCJ,1), EJ(KEJ,1), Z(KZ,1) DIMENSION W(3,3), T(3,3) C SUBROUTINE TO CALCULATE FINITE ELEMENT ... C C DIRECTION COSINE MATRIX C FOR A COMEINED AXIAL-TORSION-BENDING BAR ELEMENT. THE DIRECTION COSINE MATRIX RELATES LOCAL COORDINATE DISPLACEMENTS TO GLOBAL COORDINATE DISPLACEMENTS. THE LOCAL COORDINATE SYSTEM ASSUMES THE BAR TO LIE IN THE X-Y PLANE WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS, REFERENCE POINT 3 (TO DEFINE THE LOCAL X-Y PLANE) IS IN THE POSITIVE Y DIPECTION. C ROW ORDER (LOCAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS C C DX1, DX2, TX1, TX2, DY1, DY2, T21, TZ2, DZ1, DZ2, TY1, TY2 WHERE DX, DY, DZ ARE TRANSLATIONS AND TX, TY, TZ ARE ROTATIONS. C COLUMN ORDER (GLOBAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS C (U,V,W,P,Q,R) JOINT 1, THEN JOINT 2 WHERE U, V, W ARE TRANSLATIONS AND P,Q,R ARE ROTATIONS. C EULER ANGLE CONVENTION IS GLOBAL X,Y, 2 PERMUTATION. CALLS FORMA SUBROUTINES EULEP, MULTB, ZZBOMB. DEVELOPED BY RL WOHLEN. FEBRUARY 1973. LAST REVISION BY WA BENFIELD. MARCH 1976. C C SUBROUTINE ARGUMENTS C C CJ = INFUT MATRIX OF GLOBAL X,Y,Z COORDINATES AT BAR JOINTS. C ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES. C COLS 1,2 CORRESPOND TO JOINTS 1,2. COL 3 CORRESPONDS C TO REFERENCE POINT TO DEFINE LOCAL XY PLANE. SIZE(3,3). C ٤J = INPUT MATRIX OF EULER ANGLES (DEGREES) AT BAR JOINTS. C ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION. C COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2). C = OUTPUT DIRECTION COSINE MATRIX. SIZE(12,12). Z C KCJ = INPUT ROW DIMENSION OF CJ IN CALLING PROGRAM. C ROW DIMENSION OF EJ IN CALLING PROGRAM. KEJ = INPUT C ΚZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=12. C NERROR EXPLANATION C 1 = DIMENSION SIZE LESS THAN 12. NERROR = 1 IF (KZ .LT. 12) GO TO 999  $PX = CJ(1,2) \sim CJ(1,1)$ PY = CJ(2,2)-CJ(2,1)PZ = CJ(3,2)-CJ(3,1)PL = SQRT(PX\*\*2 + PY\*\*2 + PZ\*\*2)RX = PY\*(CJ(3,3)-CJ(3,1)) - PZ\*(CJ(2,3)-CJ(2,1))RY = PZ\*(CJ(1,3)-CJ(1,1)) - PX\*(CJ(3,3)-CJ(3,1))RZ = PX\*(CJ(2,3)-CJ(2,1)) - PY\*(CJ(1,3)-CJ(1,1))RL = SORT(RX\*\*2 + RY\*\*2 + RZ\*\*2)QX = RY\*52 - RZ\*PYQY = RZ\*PX - RX\*PZQZ = RX\*PY - RY\*PXQL = SQRT(QX\*\*2 + QY\*\*2 + QZ\*\*2)W(1,1) = PX/PL

```
W(1,2) = PY/PL
   W(1,3) = PZ/PL
   W(2,1) = QX/QL
   W(2,2) = QY/QL
   W(2,3) = CZ/OL
    W(3,1) = RX/RL
    W(3,2) = RY/RL
    V(3,3) = RZ/RL
    DO 10 J=1,12
    [0\ 10\ I=1,12]
 10 \% (I,J) = 0.0
   CALL EULER (FJ(1,1),T,3)
CALL MULTB (W,T, 3,3,3, 3,3)
    DC 22 J=1,3
    Z(1,J) = T(1,J)
    Z(5,J) = T(2,J)
    Z(9,J) = T(3,J)
    JP3 = J+3
    2(3,JP3) = T(1,J)
    2(7,JP3) = T(3,J)
 22 Z(11,JP3) = T(2,J)
    CALL EULER (EJ(1,2), T,3)
    CALL MULTR (W,T, 3,3,3, 3,3)
    DO 24 J=1.3
    JP6 = J+6
    Z(2,JP6) = T(1,J)
    Z(6,JP6) = T(2,J)
    Z(10,JP6) = T(3,J)
    JP9 = J+9
    Z(4,JP9) = T(1,J)
    2(8,JP9) = T(3,J)
 24 7(12,JP9) = 7(2,J)
    FITURN
999 CALL ZZBOMB (6HDCOS1B , NERROR)
    END
```

```
SUBPOUTINE DCDS2 (Cd.,EJ,Z,KCJ,KEJ,KZ)
      DIMENSION CJ(KCJ,1), EJ(KFJ,1); Z(KZ,1)
      DIMENSION W(3,3), T(3,3)
   SUBROUTINE TO CALCULATE FINITE ELEMENT ...
      DIRECTION CUSING MATRIX
   FOR A COMPINED MEMBRANE-PENDING TRIANGLE PLATE ELEMENT.
   THE DIRECTION COSINE MATRIX RELATES LOCAL COORDINATE DISPLACEMENTS
   TO GLOBAL COORDINATE DISPLACEMENTS.
   THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLANE
C
   WITH JOINT 1 AT THE CRIGIN, JOINT 2 LIES ALONG THE POSITIVE
C
   X AXIS, AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
   ROW OPDER (LOCAL COOPDINATE OPDER) OF DIRECTION COSINE MATRIX IS
C
      (DX,DY,TZ) JOINT 1, THEN JOINT 2, 3, MEXT
      (DZ,TX,TY) JOINT 1, THEN JOINT 2, 3
   WHERE DX. TY, DZ ARE TRANSLATIONS AND TX. TY, TZ ARE ROTATIONS.
C
   COLUMN OFDER (GLOEAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
      (U,V,W,P,C,F) JOINT 1. THEN JOINT :, 3.
   WHERE U, V, W ARE TRANSLATIONS AND P, C, R ARE ROTATIONS.
   EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
   CALLS FORMA SUBROUTINES EULER, MULTB, 22BOMB.
   DEVELOPED BY WA BENFIELD. FEBRUARY 1973.
C
   LAST REVISION BY WA BENFIELD. MARCH 1976.
C
      SUBROUTINE ARGUMENTS
Ù
                   MATRIX OF GLOBAL X,Y,Z COOPDINATES AT TRIANGLE JOINTS.
C
   LJ
          = INPUT
C
                   ROWS 1,2,3 CORRESPOND TO X:Y,Z COORDINATES.
C
                   COLS 1,2,3 CORPESPOND TO JOINTS 1,2,3. SIZE(3,3).
                   MATRIX OF EULER ANGLES (DEGREES) AT TRIANGLE JOINTS.
C
   EJ
          = INPUT
                   ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C
                   COLS 1,2,3 CORPESPOND TO JOINTS 1,2,3. SIZE(3,3).
C
          = OUTPUT DIRECTION COSINE MATRIX. SIZE(18,18).
C
                  FOR DIMENSION 'T CJ IN CALLING PROGRAM.
C
   KCJ
          = INPUT
                   ROW DIMENSION OF EJ IN CALLING PPOGRAM.
C
   KEJ
          = INPUT
C
   ΚZ
          = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=18.
C
      NEERCR EXPLANATION
C
   1 = DIMENSION SIZE LESS THAN 18.
C
C
                                                                  NERROR=1
      IF (KZ .LT. 18) 00 TO 999
      PX = CJ(1,2)-CJ(1,1)
      PY = CJ(2,2)-CJ(2,1)
      PZ = CJ(3,2)-CJ(3,1)
      PL = SQFT(PX**2 + PY**2 + PZ**2)
      FX = PY*(CJ(3,3)-CJ(3,1)) - PZ*(CJ(2,3)-CJ(2,1))
      RY = PZ*(CJ(1,3)-CJ(1,1)) - PX*(CJ(3,3)-CJ(3,1))
      RZ = PX*(CJ(2,3)\cdot CJ(2,1)) - PY*(CJ(1,3)-CJ(1,1))
      RL = SCRT(RX**2 + RY**2 + RZ**2)
      QX = RY*PZ -- RZ*PY
      CY = RZ *PX - RX *PZ
      QZ = RX*PY - FY*PX
      GL = SQRT(GX**2 + QY**2 + QZ**2)
      W(1,1) = PX/FL
      W(1.2) = PY/PL
```

```
W(1,3) = PZ/PL
      W(2.1) = QX/QL
      W(2,2) = QY/QL
      W(2,3) = CZ/QL
      W(3,1) = RX/RL
      W(3,2) = RY/RL
      W(3,3) = RZ/RL
      DC 10 J=1,18
      DC 10 I=1,18
   10\ 2(1,J) = 0.0
      DO 50 NW=1.3
      CALL EULER (EJ(1,NW),T,3)
      CALL MULTE (W,T, 3,3,3, 3,3)
      IZZ = 3*(NW-1)
      J22 = 6*(NW-1)
      DO 50 JW=1.3
      JZ = JZZ+JW
      Z(1ZZ + 1, JZ) = T(1, JW)
      Z(IZZ+2,JZ) = T(2,JW)
      Z(1ZZ+1C,JZ) = T(3,JW)
      JZ = JZ+3
      Z(1ZZ + 3, JZ) = T(3, JW)
      Z(IZZ+11,JZ) = T(1,JW)
   50 \ Z(IZZ+12+JZ) = T(2+JW)
      RETURN
C
  999 CALL ZZBOME (6HDCOS2 ,NERROR)
      END
```

```
SUERPUTINE DCDS3C (CJ,EJ,Z,KCJ,KEJ,KZ)
      DIMENSION CJ(KCJ,1), EJ(KEJ,1), Z(K2,1)
      DIMENSION W(2.3), T(3.3)
€
   SUBROUTINE TO CALCULATE FINITE ELEMENT ...
      DIRECTION COSINE MATRIX
   FOR A RECTANGULAR SHEAP PANEL ELEMENT.
   THE DIRECTION COSINE MATRIX RELATES LOCAL COORDINATE DISPLACEMENTS
   TO GLOBAL COORDINATE DISPLACEMENTS.
   THE LCCAL COORDINATE SYSTEM ASSUMES THE PANEL TO LIE IN AN X-Y PLANE
   WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIFS ALONG THE POSITIVE
   X AXIS, JOINT 3 IS IN THE POSITIVE X.Y DIRECTION, AND JOINT 4 LIES
   ALONG THE POSITIVE Y AXIS.
   ROW CROER (LOCAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
      DX1,DX2,DX3,DX4, DY1,DY2,DY3,DY4
   WHERE DX.DY ARE TRANSLATIONS.
   COLUMN ORDER (GLUFAL COORDINATE ORDER) OF DIRECTION COSINE MATRIX IS
      (U, V, W) JOINT 1, THEN JOINT 2, 3, 4.
   WHERE U, V, W PPE TRANSLATIONS.
   EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C
C
   CALLS FORMA SUBROUTINES EULER, MULTB, ZZBOMB.
   DEVELOPED BY RL WOHLEN. APRIL 1974.
C
   LAST REVISION BY WA BENFIELD. MARCH 1976.
C
C
C
      SUBROUTINE ARGUMENTS
          = INPUT MATRIX OF GLOBAL X,Y, 2 COORDINATES AT PANEL JOINTS.
C
                   FOWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C
C
                   COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C
          = INPUT
                   MATRIX OF EULER ANGLES (DEGREES) AT PANEL JOINTS.
   EJ
C
                   FOWS 1,2,3 COPPESPOND TO GLOPAL X,Y,2 PERMUTATION.
                   COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C
C
          = CUTPUT DIRECTION COSINE MATRIX. SIZE(8,12).
C
   KCJ
          = INPUT
                  ROW DIMENSION OF CJ IN CALLING PROGRAM.
C
   KEJ
          = INPUT
                   POW DIMENSION OF EJ IN CALLING PROGRAM.
          = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=8.
C
   KZ
C
      NEPROR EXPLANATION
C
C
  1 = DIMENSION SIZE TOO SMALL.
                                                                 NERROR=1
      IF (KZ .LT. E) 60 70 999
      PX = CJ(1,2)-CJ(1,1)
      PY = CJ(2,2)-CJ(2,1)
      PZ = CJ(3,2)-CJ(3,1)
      PL = SQFT(PX**2 + PY**2 + PZ**2)
      CX = CJ(1,4)-CJ(1,1)
      CY = CJ(2,4)-CJ(2,1)
      CZ = (J(3,4)-CJ(3,1)
      CL = SURT(CX**2 + CY**2 + CZ**2)
      W(1,1) = PX/PL
      W(1,2) = PY/PL
      W(1,3) = P2/PL
      W(2,1) = GX/CL
```

W(2,2) = GY/GLW(2,3) = GZ/GL

```
DO 10 J=1,12

DO 10 I=1,8

10 Z(I,J) = 0.0

DO 50 IJNT=1,4

CALL EULER (EJ(1,IJNT),T,3)

CALL MULTP (W,T, 2,3,3, 2,3)

JZZ = 3*(IJNT-1)

DO 50 JW=1,3

JZ = JZZ+JW

Z(IJNT ,JZ) = T(1,JW)

50 Z(IJNT+4,JZ) = T(2,JW)

RETURN

C

999 CALL ZZBOMB (6MDCOS3C,NERROR)

END
```

```
SUBROUTINE EULER (E.R.KR)
      DIMENSION E(1),R(KR,1)
C
  CILCULATE EULER ANGLE ROTATION TRANSFORMATION MATRIX.
C
C
  EUPER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
   DEVELOPED BY CO BODLEY. MARCH 1973.
C
_C __
      SUBROUTINE ARGUMENTS
..C
E E
          = INPUT VECTOR OF JOINT EULER ANGLES (DEGREES).
C
                    LOCATIONS 1,2,3 CORRESPOND TO THE GLOBAL X,Y,Z
C
                    PERMUTATION. SIZE(3).
C
          = OUTPUT EULER POTATION TRANSFORMATION MATPIX. SIZE(3,3).
   R
          = INPUT ROW DIMENSION OF R IN CALLING PROGRAM.
C
   KiR
C
      DICR = ATAN2(1...1.)/45.
C
      C1 = COS(E(1)*DTOR)
      C2 = CCS(E(2)*DTCP)
      C3 = CCS(E(3)*DTOR)
      S1 = SIN(E(1)*DTGR)
      S2 = SIN(E(2)*DTQP)
       S3 = SIN(E(3)*DTOR)
C
      F(1.1) - C2*C3
      F(2,2) = -C2*S3
      R(1,3) = S2
       R(2,1) = C1*S3 + S1*S2*C3
      R(2,2) = (1*C3 - 51*52*53)
      F(2,3) = -S1*C2
      R(3,1) = S1*S3 - C1*S2*C3
      R(3,2) = S1*C3 + C1*S2*S3
      R(3,3) = CI-C2
C
      RETURN
```

END

```
SUBROUTINE FINEL
                       (XYZ, JDCF, EUL, NUTEL, NJ,
                         NUTM, NUTK, NUTLT, NUTST, NUTB, V, LV, KV,
                         KRX, KRJ, KRE, NUTMX, NUTKX, NUT1, NUT2, NUT3}
      DIMENSION XYZ(KRX,1), JDOF(KRJ,1), FUL(KRE,1), V(1), LV(1)
      DIMENSION W1(24,24), W2(24,24), W3(24,24)
      DATA KW/24/, IBLANK/6H
                                  /, I1/1/
     DATA NIT, NOT/5,6/
C
   SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT ...
      AUSEMELED MASS MATRIX (ON NUTM).
      ASSEMBLED STIFFNESS MATRIX (ON NUTK),
€.
      FLEMENT LOCAL LOAD TRANSFORMATION MATRICES, IVECS (ON NUTLT),
      ELEMENT GLOBAL LOAD TRANSFORMATION MATRICES. IVECS (ON NUTKX).
      ELEMENT STRESS TRANSFORMATION MATRICES, IVECS (ON NUTST),
C
      ELEMENT UNIT LOAD BUCKLING MATRICES, IVECS (ON NUTB).
C
   IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
      IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
                  OMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINS
      IVEC(3)=0
                  ELEMENT DOF 3 TO ZERO MOTION.
   DATA ARRANGEMENT ON NUTM, NUTK FOR THE ASSEMBLED MATRICES IS IN
   SPARSE (Y) FORMA SUBPOUTINE FORMAT.
   DATA APRANGEMENT ON NUTLT, NUTKX, NUTST, NUTP FOR EACH FINITE
   ELEMENT (WPITTEN IN SUBROUTINE AXIAL, BAR, ETC) IS
      WRITE (NUTW) NAMEW, NEL, NR, NC, NAMEL (IBLANK, I=1,5),
C
                   ((W(I,J),I=I,NR),J=1,NC),(IVEC{I},I=1,NC)
Ç
      NAMEW = NAMELT, NAMEKX, NAMEST, OR NAMEB.
C
      NAMEL = AXIAL, PAP, ETC.
C
   LAST RECORD (TO DENOTE TERMINATION) IS,
€
      WRITE (NUTW) IELANK, (II, I=1,30)
   THE FOLLOWING UTILITY TAPES USE BASIC FORTRAN READ, WRITE. DO NOT
C
C
   USE THESE TAPES IN SPARSE (Y) FORMA SUPRCUTINES WHICH USE FORMA
   SUBROUTINES YIN, YOUT (BECAUSE THEY USE BUFFER IN, BUFFER OUT).
C
C
      NUTLT, NUTST, NUTMX, NUTKX, NUTP.
   THE FOLLOWING UTILITY TAPES USE FORMA YIN: YOUT.
C
C
      NUTM, NUTK, NUT1, NUT2, NUT3.
                                       ,FLUID ,GRAVTY,PAGEHD,QUAD
C
   CALLS FORMA SUPROUTINES AXIAL ,BAR
C
                           RECTSP, TONGL , YRVAD2, ZZBOMB.
C
   DEVELOPED BY WA BENFIELD, CS BODLEY, RL WOHLEN. JANUARY 1973.
C
   LAST REVISION BY RE WOHLEN. MAY 1976.
C
   · 本本本本共共共共共共共共共共和国的共和国的
C
   INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = 5, DATA IS
C
C
   READ FROM CARDS.
                                                  FORMAT (A6)
C
   50 NAMEL
      IF (NAMEL .EQ. 6HRETURN) RETURN
C
                                            (SEE SUBRT FOR INPUT)
      IF (NAMEL .EC. 6HAXIAL ) CALL AXIAL
C
      IF (NAMEL .EQ. CHEAP
                             1 CALL BAR
                                            (SEE SUERT FOR INPUT)
C
      IF (NAMEL .FQ. 6HFLUID ) CALL FLUID (SEE SUBRT FOR INPUT)
C
      IF (NAMEL .EQ. 6HGPAVTY) CALL GRAVTY (SEE SUBRT FOR INPUT)
C
                                           (SEE SUPPT FOR INPUT)
      IF (NAMEL .FQ. 6HQUAD ) CALL QUAD
ũ
      IF (NAMEL sec. 6HRECTSP) CALL RECYTSP (SEE SUERT FOR INPUT)
C
      IF (NAMEL .EQ. 6HTRNGL ) CALL TRNGL (SEE SUBRT FOR INPUT)
C
C
      GO TO 50
C
   DEFINITION OF INPUT VAPIABLES.
```

```
NAMEL = AXIAL, BAR, ETC AS SHOWN ABOVE. GIVES SUBROUTINE CALLED.
C
C
C
   EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C
      A = ANY KEYPUNCH SYMBOL.
C
      X = CARD COLUMNS SKIPPED.
C
   C
C
      SUBROUTINE ARGUMENTS (ALL INPUT)
C
   XYZ
          = MATRIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWS CORRESPOND
C
            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C
            X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ,3).
C
            MAY BE EQUIVALENCED TO V(1) IN CALLING PROGRAM.
C
   JDQF
          = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND
C
            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C
            TRANSLATION DOFS AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
C
            ROTATION DOFS. SIZE (NJ.6).
C
            MAY BE EQUIVALENCED TO LV(1) IN CALLING PROGRAM.
          = MATRIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND
C
   EUL
C
            TO JOINT NUMBERS. COLUMNS 1,2,3 COPRESPOND TO THE
C
            GLOPAL X,Y,2 PERMUTATION. SIZE(NJ,3). MAY BE
C
            EQUIVALENCED TO V(KRX*(XYZ COL DIM)+1) IN CALLING PROGRAM.
C
   NUTEL
          = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
            THIS SUBPOUTINE AND SUBROUTINES AXIAL, ETC GIVEN BY NAMEL.
C
C
            IF NUTEL = 5, DATA WILL BE READ FROM CARDS.
C
   NJ
          = NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JDOF), (EUL).
C
   NUTM
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ASSEMBLED
C
            MASS MATRIX IS CUTPUT IN SPARSE NOTATION.
C
            NUTH MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C
            USES FORMA YIN, YOUT.
C
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ASSEMBLED
   NUTK
C
            STIFFNESS MATRIX IS GUTPUT IN SPARSE NOTATION.
C
            NUTK MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C
            USES FORMA YIN, YOUT.
C
   NUTLT
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LO' L
C
            LCAD TRANSFORMATION MATRICES AND IVECS ARE CUTPUT.
C
            NUTLY MAY BE ZERO IF LOAD TRANSFORMATIONS ARE NOT FORMED.
C
            USES FORTRAN READ, WRITE.
C
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
   NUTST
C
            STRESS TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C
            NUTST MAY BE ZERO IF STRESS TRANSFORMATIONS ARE NOT FORMED.
C
            USES FORTRAN READ, WRITE.
C
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT UNIT LOAD
   NUTB
            BUCKLING MATRICES AND IVECS ARE OUTPUT.
€.
C
            NUTB MAY BE ZERO IF BUCKLING MATRICES ARE NOT FORMED.
C
            USES FORTRAN READ, WRITE.
C
   ٧
          = VECTOR WORK SPACE.
C
   L۷
          = VECTOR WORK SPACE.
C
          = DIMENSION SIZE OF V.LV IN CALLING PROGRAM.
   KV
          = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
C
   KRX
C
   KRJ
          = POW DIMENSION OF JOHF IN CALLING PROGRAM.
C
   KRE
          = ROW DIMENSION OF EUL IN CALLING PROGRAM.
C
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
   NUTMX
            MASS MATRICES AND IVECS ARE STORED.
C
C
            NUTMX MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C
            USES FORTRAN READ, WRITE.
```

```
NUTKX = LCGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C
            STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
C
            MATRICES) AND IVECS ARE STORED.
            NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C
            USES FORTRAN READ, WRITE.
C
          = LCGICAL NUMBER OF UTILITY TAPE. USES FORMA YIN. YOUT.
   NUT1
C
          = LOGICAL NUMBER OF UTILITY TAPE. USES FORMA YIN, YOUT.
   NUT2
          = LOGICAL NUMBER OF UTILITY TAPE. USES FORMA YIN, YOUT.
C
   NUT3
      MERROR
C
             EXPLANATION
   1 = NAMEL IMPROPERLY DEFINED.
€
 1001 FORMAT (A6)
 2001 FORMAT (//41x 35HJOINT DATA USED IN SUBROUTINE FINEL)
 2002 FORMAT (//35X 47HJOINT DATA USED IN SUBROUTINE FINEL (CONTINUED))
 2003 FORMAT ( /16X 18HDEGREES OF FREEDOM
                18X 28HGLOBAL CARTESIAN COORDINATES
                12X 22HEULER ANGLES (DEGREES)
               114X 11HTRANSLATION 8X 8HROTATION
                / 2X5HJOINT 6X1HU 5X1HV 5X1HW FX1HP 5X1HQ 5X1HR
                IIXIHX IIXIHY IIXIHZ 14XIHX 10XIHY 10XIHZ /)
 2004 FORMAT (1X I5, 3X 6I6, 3X 3F12.4, 4X 3F11.4)
      IF (NUTMX .GT. G) REWIND NUTMX
      IF (NUTKX .GT. O) REWIND NUTKX
      IF (NUTE .GT. C) REWIND NUTE
      IF INUTLY .GT. C) PEWIND NUTLY
      IF (NUTST .GT. 0) REWIND NUTST
C
   DETERMINE SIZE OF FINAL MASS-STIFFNESS MATRIX FROM THE MAXIMUM DOF
C
   NUMBER IN JOCE.
      NDOF = JDOF(1.1)
     DO 35 I=1.NJ
      DO 35 J=1,6
      IF (JDOF(I,J) .GT. NDOF) NDCF=JDOF(I,J)
   35 CONTINUE
C
   PRINT JOINT DOF, XYZ COORDINATES, EULER ANGLES.
      CALL PAGEND
      WRITE (NCT, 2001)
      WRITE (NOT, 2003)
      NLINE = 0
      DO 40 IJ=1,NJ
      NLINE = NLINE+1
      IF (NLINE .LE. 42) GO TO 40
      CALL PAGEND
      WRITE (NOT, 2002)
      WPITE (NOT, 2003)
      NLINE = 1
   40 WRITE (NOT,2004) IJ, (JDOF(IJ,J), J=1,6), (XYZ(IJ,J), J=1,3),
                        (EUL(IJ,J), J=1,3)
   READ FINITE ELEMENT TYPE.
   50 READ (NUTEL, 1001) NAMEL
      IF (NAMEL .EQ. 6HRETURN) GO TO 500
```

```
IF (NAMEL .FQ. 6HAXIAL ) GC TO 110
      IF (NAMEL .EQ. 6HEAR
                              ) GO TO 140
      IF (NAMEL .EQ. 6HTRNGL ) GO TO 150
      IF (NAMEL .EQ. 6HFLUID ) GO TO 151
                              ) 60 TO 160
      IF (NAMEL .EC. 6HCUAD
      IF (NAMEL .EQ. 6HRECTSP) GO TO 162
      IF (NAMEL .EQ. 6HGRAVTY) GO TO 171
                                                               NERROR=1
                                                                   GD TO 999
  BAR FINITE ELEMENT (AXIAL ONLY).
  110 CALL AXIAL (XYZ, JDCF, EUL, NUTEL, NJ,
                    NUTMX, NUTKX, NUTLT, NUTST,
                    Wi, W2, W3, KRX, KRJ, KRE, KW)
      GO TO 50
  BAR FINITE ELEMENT (COMBINED AXIAL, TORSION, BENDING).
  140 CALL BAR
                   (XYZ, JDCF, EUL, NUTEL, NJ,
                    NUTMX, NUTKX, NUTB, NUTLT, NUTST,
     *
                    W1.W2,W3,KRX,KRJ,KRE,KW)
      GD TO 50
  TRIANGULAR PLATE ELEMENT.
  150 CALL TRNGL
                  (XYZ, JDOF, EUL, NUTEL, NJ,
                    NUTMX, NUTKX, NUTB, NUTLT, NUTST,
                    W1,W2,W3,KRX,KRJ,KRE,KW)
      GD TO 50
  FLUID ELEMENT.
  151 CALL FLUID (XYZ, JDOF, EUL, NUTEL, NJ,
                                       NUTLT, NUTST,
                    NUTMX, NUTKX,
                    WI, W2, W3, KRX, KRJ, KRE, KW1
      GO TO 50
  QUADRILATERAL PLATE FLEMENT.
  160 CALL QUAD
                   (XYZ, JDCF, EUL, NUTEL, NJ,
                    NUTMX, NUTKX, NUTR, NUTLT, NUTST,
                    WI, W2, W3, KRX, KR3, KRE, KW)
      GO TO 50
  RECTANGULAR SHEAR PANEL.
  162 CALL RECTSP (XYZ, JDCF, EUL, NUTEL, NJ,
                    NUTMX.NUTKX.NUTLT.NUTST.
                    WI, W2, W3, KRX, KRJ, KRE, YW)
      GO TO 50
   GRAVITY FLEMENT.
  171 CALL GRAVTY (XYZ, JDOF, EUL, NUTEL, NJ,
     *
                          NUTKX,
     *
                    WI, W2, W3, KRX, KRJ, KRE, KW)
      GO TO 50
C
   TERMINATE FINITE ELEMENT DATA ON STORAGE DISKS.
  500 IF (NUTMX .GT. 0) WRITE (NUTMX) IBLANK, (II, I=1,30)
      IF (NUTKX .GT. G) WRITE (NUTKX) IBLANK, (II, I=1,30)
                 .GT. 0) WPITE (NUTE) IBLANK, (11, 1=1,30)
      IF (NUTP
      IF (NUTLT .GT. C) WRITE (NUTLT) IBLANK, (II, I=1,30)
      IF (NUTST .GT. 0) WRITE (NUTST) IBLANK, (I1, I=1,30)
C
   SUM FINITE ELFMENT MATRICES.
      IF (NUTM.GT.G) CALL YZERO (NUTM, NDOF, NDOF)
```

IF (NUTK.GT.O) CALL YZERO (NUTK, NDOF, NDOF)

IF (NUTMX .GT. 0) CALL YRVAD2 (NUTMX,NUTM,NDDF,W!,KW,V,LV,KV,

\* NUT1,NUT2,NUT3)

IF (NUTKX .GT. 0) CALL YRVAD2 (NUTKX,NUTK,NDDF,W1,KW,V,LV,KV,

\* NUT1,NUT2,NUT3)

RETURN

C

999 CALL ZZBOM6 (6HFINEL ,NERROR)
END

```
SUBROUTINE FLUID (XYZ, JDCF, EUL, NUTEL, NJ,
                             NUTLT, NUTST,
           NUTMX, NUTKX,
           W, T, S, KX, KJ, KE, KW)
     DIMENSION XYZ(Kx,1),JDOF(KJ,1), EUL(KE,1), W(KW,1),
          T(KW,1), S(KW,1)
     DIMENSION CJ(3,8),EJ(3,8),IV1(24),IVTET(12),JM(4,16),VL(10),
              DV(12),DIST(12,12),TV(24)
                                         /, J1ST /0/
      DATA NRW, NRST/24,1/, IBLNK/6H
      DATA NIT, NOT/ 5,6 /
      DATA NAMEL / 6HFLUID
      DATA KCJ / 3 / 1 CKJM / 4 /
     DATA KDIST / 12 / , IFBAD / 1 / DATA JM/1,2,3,4, 3,6,4,2, 2,6,4,5, 3,5,1,2,
              1,3,6,5, 1,6,4,5, 2,7,4,5, 1,2,4,5,
     *
              4,7,8,5, 5,2,7,6, 4,2,3,7, 1,3,8,6,
              1,6,8,5, 1,3,4,8, 1,2,3,6, 8,3,7,6 /
C
   SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT ...
      MASS MATRICES AND LVECS (ON NUTMY),
C
C
      STIFFNESS MATRICES (SAME AS GLOBAL LOAD TRANSFORMATION MATRICES)
C
      AND IVECS (ON NUTKX),
      PRESSURE TRANSFORMATION MATRICES AND IVECS (ON NUTST).
C
   FOR FLUID ELFMENTS.
C
   ELEMENT SHAPE MAY BE TETRAHEDRON, PENTAHEDRON, OR HEXAHEDRON.
C
C
  MASS, STIFFNESS MATRICES ARE IN GLOBAL COORDINATE DIRECTIONS.
C
   GLOBAL COORDINATE ORDER IS
C
      (U,V,W) JOINT 1, THEN JOINT 2,3,4,(5,6,7,8).
   WHERE U, V, W ARE TRANSLATIONS.
C
   IVEC GIVES ELFMENT DOF INTO GLOBAL DOF. EXAMPLES...
C
      IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
C
                  OMITS ELEMENT DOF 3 FROM GLOPAL DOF. THIS CONSTRAINS
      IVEC(3)=0
                  ELEMENT DOF 3 TO ZERO MOTION.
C
  PRESSURE TRANSFORMATION MATRICES RELATE CHANGE IN PRESSURE (DUE TO
C
C
  COMPRESSIBILITY) TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
   PRESSURE CHANGE WITHIN THE FLUID ELEMENT IS CONSTANT. STATIC PRESSURE
C
   DUE TO GRAVITY AND FLUID HEIGHT IS NOT INCLUDED.
C
   DATA ARRANGEMENT ON NUTMX, NUTKX, NUTST FOR EACH FINITE ELEMENT IS
C
C
   (W=M,K,ST)
C
      WRITE (NUTWX) NAMEW, NEL, NP, NC, NAMEL, (IBLNK, I=1,5),
                     ((W(I,J),I=1,NR),J=1,NC),(IVEC(I),I=1,NC)
   CALLS FORMA SUBROUTINES TEGEOM, VCROSS, VDOT ,ZZBOMB.
   DEVELOPED BY C S BODLEY. FEBRUARY 1974.
C
   LAST REVISION BY WA BENFIELD. MARCH 1976.
C
C
   INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = NIT, DATA IS
C
   READ FROM CARDS.
      NAMEM, NAMEK, NAMELT, NAMEST
C
                                                    FORMAT (4(A6,4X)
C
                                                    FORMAT (2(5X,E10))
      RC, BKM
C
   20 NEL, J1, J2, J3, J4, J5, J6, J7, J8
                                                    FORMAT (915)
C
      IF (J1 .EQ. O) RETURN
C
      GC TO 20
C
C
  DEFINITION OF INPUT VARIABLES.
   NAMEM = TYPE OF MASS MATRIX WANTED.
          = M1, LUMPED MASS MATRIX.
```

```
= M2. QUASI-IRROTATIONAL CONSISTENT MASS MATRIX.
          = M3, IRROTATIONAL MASS MATRIX.
                       OR 6HNOMASS, NO MASS MATRIX CALCULATED.
   NAMEK
          = TYPE OF STIFFNESS MATRIX WANTED.
C
            = K1, LINEAR DISPLACEMENT ASSUMED.
C
                       OR 6HNOSTIF, NO STIFFNESS MATRIX CALCULATED.
   NAMELT = IDENTIFICATION NAME FOR LOAD TRANSFORMATION MATRICES. (NOT YET).
C
   NAMEST = IDENTIFICATION NAME FOR PRESSURE TRANSFORMATION MATRICES.
                       OR 6HNOSTRS, NO PRESSURE TRANSFORMATIONS CALCULATED.
            = 6H
          - MASS DENSITY.
C
   RO
C
   {\sf BKM}
          = BULK MODULUS.
C
          = FINITE ELEMENT NUMBER. FOR REFERENCE ONLY, NOT USED IN
   NEL
            CALCULATIONS. WRITTEN ON NUTMX, ETC.
C
          = JOINT NUMBER AT ELEMENT VERTEX 1.
   Jl
          = JOINT NUMBER AT ELEMENT VERTEX 2.
C
   J2
C
   J3
            JOINT NUMBER AT ELEMENT VERTEX 3.
C
          = JOINT NUMBER AT ELEMENT VERTEX 4.
   J4
            FOR A TETRAHEDRON. FACE 1,2,3 MUST BE NUMBERED CLOCKWISE AS
C
C
            VIEWED FROM OUTSIDE THE ELEMENT.
C
   J5
          = JOINT NUMBER AT ELEMENT VERTEX 5. (USED FOR PENTAHEDRON AND
C
            HEXAHEDRON).
          = JOINT NUMBER AT ELEMENT VERTEX 6. (USED FOR PENTAHEDRON AND
C
   J6
C
            HEXAHEDRON) -
C
            FOR A PENTAHEDRON, FACE 1,2,3 MUST BE NUMBERED CLOCKWISE AS
C
            VIEWED FROM OUTSIDE THE ELEMENT. FACE 4,5,6 IS NUMBERED IN
C
            THE SAME ORDER AS FACE 1,2,3. A LINE JOINING JOINTS 1 AND 4
C
            MUST FORM AN EDGE OF THE PENTAHEDRON.
C
          = JOINT NUMBER AT ELEMENT VERTE: 7. (USED FOR HEXAHEDRON).
   J7
C
          = JOINT NUMBER AT ELEMENT VERTEX 8. (USED FOR HEXAHEDRON).
   J8
C
            FOR A HEXAHEDRON, FACE 1,2,3,4 MUST BE NUMBERED CLOCKWISE
C
            AS VIEWED FROM CUTSIDE THE ELEMENT. FACE 5,6,7,8 IS NUMBERED
C
            IN THE SAME ORDER AS FACE 1,2,3,4. A LINE JOINING JOINTS 1
C
            AND 5 MUST FORM AN EDGE OF THE HEXAHEDRON.
C
C
   EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C
      I = INTEGER DATA, RIGHT ADJUSTED.
C
      E = DECIMAL POINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED.
      X = CARD COLUMNS SKIPPED.
C
C
      SUBROUTINE ARGUMENTS (ALL INPUT)
C
          = MATRIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWL CORRESPOND
C
   XYZ
C
            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C.
            X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ,3).
C
   JDOF
          = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND
C
            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C
            TRANSLATION DOES AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
C
            ROTATION DOFS. SIZE(NJ,6).
C
   EUL
          MATRIX OF JUINT EULER ANGLES (DEGREES). ROWS CORRESPOND
C
            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
C
            GLOBAL X,Y,Z PERMUTATION, SIZE(NJ,3).
C
          = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
   NUTEL
C
            THIS SUPROUTINE. IF NUTEL = NIT, DATA IS READ FROM CARDS.
C
          NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JDDF), (EUL).
   NJ
C
   NUTMX
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
            MASS MATRICES AND IVECS ARE OUTPUT.
```

```
C
            NUTMX MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
            USES FORTRAN READ, WRITE.
   NUTKX
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
            STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
C
            MATRICES) AND IVECS ARE OUTPUT.
C
C
            NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C
            USES FORTRAN READ, WRITE.
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOAD
   NUTLT
            TRANSFORMATION MATRICES AND IVECS ARE OUTPUT. (NOT YET).
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
   NUTST
            PRESSURE TRANSFORMATION MATRICES AND IVECS ART OUTPUT.
NUTST MAY BE ZERO IF PRESSURE TRANSFORMATIONS ARE NOT FORMED.
C
C
C
            USES FORTRAN READ, WRITE.
C
          = MATRIX WORK SPACE. MIN SIZE(24,24).
   W
   T
          = MATRIX WORK SPACE. MIN SIZE(24,24).
C
          = MATRIX WORK SPACE. MIN SIZE(24,24).
C
   KX
          = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
C
          = ROW DIMENSION OF JOOF IN CALLING PROGRAM.
   K.J
C
          = ROW DIMENSION OF EUL IN CALLING PROGRAM.
   KE
C
   KW
          = ROW DIMENSION OF W. T. AND S IN CALLING PROGRAM. MIN=24.
C
      NERROR EXPLANATION
C
   1 = INCORRECT TETRAHEDRON GEOMETRY.
   2 = INPUT JOINT NUMBER EXCEEDS MAXIMUM ALLOWABLE NUMBER CF JOINTS.
   3 = NUTMX NOT POSITIVE.
   4 = NUTKX NOT POSITUVE.
   5 = NUTST NOT POSITIVE.
 1001 FORMAT (5(A6,4X))
 1002 FORMAT (3(5X,E10.0))
 1003 FORMAT (915)
 2001 FORMAT (//25X 38HINPUT DATA FOR FLUID (TETRA, PENTA, OR
         21H HEXAHEDRON) ELEMENTS)
 2002 FORMAT (//20X 38HINPUT DATA FOR FLUID (TETRA, PENTA, OR
         33H HEXAHEDRON) ELEMENTS (CONTINUED))
 2003 FORMAT (/12X7HMASS = A6,13X7HSTIF = A6,6X13HLOAD TRANS = A6,
                 3X15HSTRESS TRANS = A6, 3X
              / 15X,4HRC = 510.3, 13X7HBULKM = E10.3,
     * // 9X7HELEMENT 6 HJOINT 3 6X7HJOINT 2 6X7HJOINT 3 6X7HJOINT 4
                       6x7HJOINT 5 6x7HJOINT 6 6x7HJOINT 7 6X7HJOINT 8
               / 9X6HNUMBER)
 2004 FORMAT (3X.9(8X.15))
 3GO1 FORMAT (51H * * * * * UNCONVENTIONAL JOINT NUMBERING * * * * * . /
               9151
C
C
      IF (11ST .EQ. 1) GD TG 3
      I1ST = 1
      DO 4 1=1,4
      11 = 3*1 - 2
      D0 4 J=1,4
      J1 = 3*J - 2
    4 CALL UNITY (DIST(II, J1), 3, KDIST)
C.
    3 NLINE = 0
```

```
CALL PAGEND
      WRITE (NOT, 2001)
      READ (NUTEL, 1001) NAMEM, NAMEK, NAMELT, NAMEST
      READ (NUTEL, 1002) RO, BKM
      WRITE (NOT, 2003) NAMEM, NAMEK, NAMELT, NAMEST,
                    RO. BKM
      IF CHAMEM .NE. 6HM3
                              ) GO TO 20
      DO 2 I=1,12
    2 DIST(I,I) = 2e
C
   20 READ (NUTEL, 1003) NEL, J1, J2, J3, J4, J5, J6, J7, J8
                                                              NERROR=1
      IF (J1.LE.O .AND. IFBAD.EQ.-1) GO TO 990
      IF (J1 .LE. 0) RETURN
      NLINE = NLINE + 1
     IF (NLINE .LE. 42) GO TO 30
      CALL PAGEND
     WRITE (NOT, 2002)
      WRITE (NOT, 2003) NAMEM, NAMEK, NAMELT, NAMEST,
             RO, BKM
      NLINE = 0
   30 WRITE (NOT, 2004) NEL, J1, J2, J3, J4, J5, J6, J7; J8
                                                              NERROR=2
      IF (J1.GT.MJ .BR. J2.GT.MJ .DP. J3.GT.MJ .DR. J4.GT.MJ) GU TO 999
      IF (J5.GT.NJ .OR. J6.GT.NJ .OR. J7.GT.NJ .OR. J8.GT.NJ) GO TO 999
C
C
  FORM FINITE ELEMENT COORDINATE LOCATIONS, EULER ANGLES, REVADD IVEC.
      LR = 10
      NJN = 8
      IF (J7 -NE. 0) 60 TO 38
      LR = 6
      NJN = 6
      IF (J5 .NE. 0) GO TO 38
      LR = 1
      NJN = 4
C
   38 NCOL = 3*NJN
      DO 5 I=1, NCCL
      DO 5 J=1, NCCL
      W(I,J) = G.
      S(I,J) = 0.
    5 T(I,J) = 0.
      DO 40 I=1,3
      CJ(1,1) = XYZ(J1,1)
      CJ(I,2) = XYZ(J2,I)
      CJ(I,3) \approx XYZ(J3,I)
      CJ(I,4) = XYZ(J4,I)
      EJ(I,I) = EUL(JI,I)
      EJ(1,2) = EUL(J2,I)
      EJ(I,3) = EUL(J3,I)
      EJ(I,4) = EUL(J4,I)
      IV1(I ) = JDOF(J1,I)
      IV1(I+3) = JDDF(J2,I)
```

```
IV1(I+6) = JDOF(J3,I)
   40 \text{ IVI}(I+9) = JDCF(J4,I)
      IF (LR .E(. 1) GO TO 50
C
      DD 42 I=1,3
      CJ(1,5) = XYZ(J5,1)
      CJ(I,6) = XYZ(J6,I)
      EJ(1,5) = EUL(J5,1)
      EJ(I,6) = EUL(J6,I)
      IVI(I+12) = JDDF(J5,I)
   42 \text{ IV1}(1+15) = \text{JDCF}(\text{J6},\text{I})
      IF (LP .EQ. 6) GO TO 50
C
      DU 44 I=1,3
      CJ(I,7) = XYZ(J7,I)
      CJ(I,9) = XYZ(J9,I)
      EJ(I,7) = EUL(J7,I)
      EJ(1,8) = EUL(J8,I)
      IV1(I+18) = JD0F(J7,I)
   44 IV1(I+21) = JauF(J6,I)
   50 DO 52 L=1.LR
      LA = L
      IF (LR.EQ.10) LA=L+6
      DO 53 I=1,4
      JNO = JM(I_{+}LA)
      L1 = 3*1 - 2
      IVTET(L1 ) = 3#JNO - 2
      IVTET(L1+1) = 3*JNO - 1
   53 \text{ IVTET(L1+2)} = 3*JNO
C
     CALL TEGEOM (CJ.JM(1, LA
                                  ), VL(L), DV,
                                                     KCJ, IFEAD)
      IF (IFBAD.NE.O) GC TO 51
      WRITE (NGT,3001) NEL, 21, J2, J3, J4, J5, J6, J7, J8
      IFBAD = -1
   51 SM = RD * VL(L) / 16.0
      IF (NAMEM .EQ. 6HM3
                              ) SM=RO*VL(L]/20.0
IF (LR .GT. 1) SM = SM/2.
    CALL REVADD (1.,DV,L,JVTET,T,1,12,LR,NCOL,1,KW)
   52 CALL REVADD "SM, BIST, IVTET, IVTET, W, 12, 12, NCOL, NCOL, KDIST, KW)
     IF (NAMEM .NE. 6HM1
                              ) GO TO 220
   -DO 210 I=1,NCOL
      SAVE = 0.0
      DO 215 J=1,NCOL
      5AVE = SAVE + W(I,J)
  215 W(I,J) = 0.0
  210 W(I,I) = SAVE
  220 IF (LR .EQ. 1) GO TO 60
      DO 55 I=2,LR
      VL(1) = VL(1) + VL(1)
      DO 55 J=1,NCOL
   55 T(1,J) = T(1,J) + T(1,J)
      VL(1) = VL(1)/2.
```

```
DC 56 J=1+MCOL
   56 T(1,J) = T(1,J)/2.
C
   60 DO 61 J=1,NCOL
   (L, I)T = (L)VT 16
     00 65 J=1.NJN
      J1 = 3*J - 2
   65 CALL EULER (EJ(1,J),S(J1,J1),KW)
      IF (NAMEST .EQ. 6H
                                .OP. NAMEST .EQ. 6HNOSTRS) GO TO 90
      CALL PRESS (CJ,T,NJN,NCOL,KCJ,KW)
      CALL MULTA (T,S,MJN,NCOL,NCOL,KW,KW)
   90 CALL BTAFA (W.S.NCOL, NCOL, KW.KW)
      CALL MULTA (TV,S,1,NCCL,NCCL,1,KW)
      BOV = EKM/VL(1)
      DO 70 I=1,NCOL
      DC 70 J=I,NCOL
      S(I_{\bullet}J) = BCV*TV(I)*TV(J)
   70 S(J,I) = S(I,J)
C
      IF (NAMEM .EQ. 6H
                               .OR. NAMEM -. EQ. 6HNCMASS) GO TO 110
                                                              NERROR=3
      IF (NUTMX .LE. 0) GD TO 999
      WRITE (NUTMX) NAMEM, NEL, NCCL, NCCL, NAMEL, (IBLNK, I=1,5),
          ((W(I,J),I=1,NCOL),J=1,NCOL), (IV1(I),I=1,NCOL)
C
                               •OR. NAMEK •EQ. 6HNOSTIF) GO TO 120
  110 IF (NAMEK .EQ. 6H
                                                              NERROR=4
      IF (NUTKX .LE. 0) GO TO 909
      WRITE (NUTKX) NAMEK, NEL, NCOL, NCOL, NAMEL, (IBLNK, I=1,5),
          ((S(I,J),I=1,NCCL),J=1,NCCL), (IV1(I),I=1,NCCL)
C
  120 IF (NAMEST .EQ. 6H
                                .UP. NAMEST .EQ. 6HNOSTRS) GO TO 20
                                                              NERROR=5
      IF (NUTST .LE. 0) GC TO 999
      NJNP1 = NJN + 1
      CALL MULT (T,S,T(NJNP1,1),NJN,NCCL,NCCL,KW,KW)
      CALL MULTA (T,W,NJN,NCOL,NCOL,KW,KW)
      NRST = 2 * NJN
      WRITE (NUTST) NAMEST, NEL, NRST, NCOL, NAMEL, VL(1), (YELNK, I=1,4),
         {(T(I, J), I=1, NRST), J=1, NCOL), (IV1(I), I=1, NCOL)
      GO TO 20
C
  999 CALL ZZBOME (6HFLUID ,NERROR)
      END
```

```
SUBROUTINE GRAVTY (XYZ, JDCF, EUL, NUTEL, NJ,
                 NUTKX .
           W, T, S, KX, KJ, KE, KW)
      DIMENSION XYZ(KX,1), JDOF(KJ,1), EUL(KE,1), W(KW,1),
           (KW,1), S(KW,1)
      DIMENSION CJ(3,4),EJ(3,4),IV1(12),IVTRI(9),JM(3,4),GV(3),EV(3)
      DATA IBLNK/6H
      DATA NIT, NOT/ 5,6 /
      DATA NAMEL / 6HGRAVTY /
      DATA KCJM / 3 /
      DATA JM / 1,2,3, 1,3,4, 1,2,4, 4,2,3 /
C
   SUBROUTINE TO CALCULATE (ON OPTION) FINITE ELEMENT ...
C
      STIFFNESS HATRICES (SAME AS GLOBAL LOAD TRANSFORMATION MATRICES)
C
      AND IVECS (CN NUTKX),
C
   FOR GRAVITY ELEMENTS.
C
   STIFFNESS MATRICES AR+ 9~ GL021~ 300R49-1T 4IR 090-S8
C
   GLOBAL COORDINATE ORDER IS
      (U,V,W) JOINT 1, THEN JOINT 2,3,(4).
C
C
   WHERE U, V, W ARE TRANSLATIONS.
C
   IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
      IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
C
C
                  OMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINS
      IVEC (3)=0
C
                  ELEMENT DOF 3 TO ZERO MOTION.
C
   DATA APRANGEMENT ON NUTKX FOR EACH FINITE ELEMENT IS
C
   (W=K)
C
      WRITE (NUTWX) NAMEW, NEL, NR, NC, NAMEL, (IBLNK, I=1,5).
C
                    ((W(I,J),I=1,NR),J=1,NC),(IVEC(I),I=1,NC)
   CALLS FORMA SUBROUTINES KGRAV , MULTA , MULTE , VCROSS, ZZBOMB.
C
   DEVELOPED BY C S BODLEY. FEBRUARY 1974.
C
C
   LAST REVISION BY WA BENFIELD. MARCH 1976.
C
C
   ************************
C
   INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = NIT, DATA IS
C
   READ FROM CARDS.
C
                                                   FORMAT (2(A6,4X)
      NAMEM - NAMEK
C
                                                   FORMAT (5X,E10)
      RC
C
      (GV(I), I=1,3)
                                                   FERMAT (3(5X,E10))
C
   20 NEL, J1, J2, J3, J4
                                                   FORMAT (515)
C
      IF (J1 .EQ. 0) RETURN
C
      GC TO 20
C
C
   DEFINITION OF INPUT VARIABLES.
   NAMEM = TYPE CF MASS MATRIX WANTED.
C
                       OR 6HNOMASS, NO MASS MATRIX CALCULATED.
C
            = 6H
C
   NAMEK
          = TYPE OF STIFFNESS MATRIX WANTED.
C
            = K1, LINEAR DISPLACEMENT ASSUMED.
C
            = 6H
                       OR 6HNOSTIF, NO STIFFNESS MATRIX CALCULATED.
C
   RO
          = MASS DENSITY.
C
   GV
          = GMAVITY VECTOR.
          = FINITE FLEMENT NUMBER. FOR REFERENCE ONLY. NOT USED IN
C
   NEL
C
            CALCULATIONS. WRITTEN ON NUTKX.
C
   J1
          = JOINT NUMBER AT FLEMENT VERTEX 1.
C
   J2
          = JOINT NUMBER AT ELEMENT VERTEX 2.
C
          = JOINT NUMBER AT ELEMENT VERTEX 3.
   J3
```

```
= JCINT NUMBER AT ELEMENT VERTEX 4. (USED FOR QUADRILATERAL).
   J4
  THE ELEMENT MUST BE NUMBERED CLOCKWISE AS VIEWED FROM THE FLUID SIDE
C
   OF THE ELEMENT.
C
C
   EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C
      I = INTEGER DATA, RIGHT ADJUSTED.
      F = DECIMAL PCINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED.
C
C
     X = CARD COLUMNS SKIPPED.
C
   C
C
      SUBROUTINE ARGUMENTS (ALL INPUT)
C
   XYZ
          = MATRIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWS CORRESPOND
            TO JOINT NUMBERS. CCLUMNS 1,2,3 CORRESPOND TO THE JOINT
C
C
           X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ.3).
C
   JDOF
         = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND
C
           TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C
           TRANSLATION DOES AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
C
           ROTATION DOFS. SIZE(NJ.6).
C
         = MATRIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND
  EUL
C
           TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
           GLOBAL X,Y,Z PERMUTATION. SIZE(NJ,3).
C
C
         = LCGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
   NUTEL
            THIS SUBROUTINE. IF NUTEL = NIT, DATA IS READ FROM CARDS.
C
          = NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JDOF), (EUL).
C
C
   NUTKX
         = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C
            STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
C
           MATRICES) AND IVECS ARE CUTPUT.
C
           NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C
           USES FORTRAN READ, WRITE.
C
         = MATRIX WORK SPACE. MIN SIZE(12,12).
  W
C
  T
         = MATRIX WORK SPACE. MIN SIZE(12,12).
C
  S
         = MATRIX WORK SPACE. MIN SIZE(12,12).
C
         = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
  ΚX
         = POW DIMENSION OF JODE IN CALLING PROGRAM.
C
  KJ
C
         = ROW DIMENSION OF EUL IN CALLING PROGRAM.
  ΚE
C
  KW
         = POW DIMENSION OF W. T. AND S IN CALLING PROGRAM. MIN=12.
     NERDER
            EXPLANATION
C
   1 = INPUT JOINT NUMBER EXCEEDS MAXIMUM ALLOWABLE NUMBER OF JOINTS.
   2 = NUTKX NOT POSITIVE.
1001 FORMAT (5(A6,4X))
 1002 FORMAT (3(5X,E10.0))
 1003 FORMAT (515)
 2001 FORMAT (//25X 45HINPUT DATA FOR GRAVITY STIFFNESS (TRIANGLE OR
                    24H QUADRILATERAL) ELEMENTS)
 2002 FURMAT (//20X
                    45HINPUT DATA FOR GRAVITY STIFFNESS (TRIANGLE OR
                    36F QUADRILATERAL) ELEMENTS (CONTINUED))
 2003 FORMAT (/12X7HMASS = A6,13X7HSTIF = A6,6X
             / 15X,4HRG = E10.3, 13X5HGVX = E10.3, 13X5HGVY = E10.3,
                                13X5HGVZ = E10.3.
    * //15X7HFLEMENT 13X7HJ0INT 1 13X7HJ0INT 2 13X7HJ0INT 3
                      13X7HJCINT 4
              /15X6HNUMPER)
 2004 FORMAT (18X,9(15,15X))
```

```
C
C
      NLINE = 0
      CALL PAGEND
      WRITE (NOT, 2001)
      READ (NUTEL, 1001) NAMEM, NAMEK
      READ (NUTEL 1002) RO
      READ (NUTFL, 1002) (GV(I), I=1,3)
      WRITE (NOT, 2003) NAMEM, NAMEK,
                    RC, (GV(I), I=1,3)
C
   .20 READ (NUTEL-1093) NEL-J1-J2-J3-J4
      IF (J1 .LE. 0) RETURN
      NLINE = NLINE + 1
      IF (NLINE .LE. 42) GC TO 30
      CALL PAGEND
      WRITE (NOT, 2002)
      WRITE (NOT, 2003) NAMEM, NAMEK,
             RC, (GV(1), I=1,3)
      NLINE = 0
   30 WRITE (NOT, 2004) NEL, J1, J2, J3, J4
                                                                     NERROR=1
      IF (J1.GT.NJ .CR. J2.GT.NJ .CR. J3.GT.NJ .CR. J4.GT.NJ) GC TO 999
C
C
  FORM FINITE ELEMENT COORDINATE LOCATIONS, EULER ANGLES, REVADD IVEC.
C
      LP = 4
      NJN = 4
      1F (J4 .NE. 0) GO TO 38
      LR = 1
      NJN = 3
   38 NCOL = 3*NUN
      DO 5 I=1,NCOL
      DO 5 J=1, NCCL
      W(I,J) = 0.
      S(I,J) \approx 0.
    5 T(I_{*}J) = 0.
C
      DO 40 I=1,3
      CJ(I,1) = XYZ(J1,I)
      CJ(1,2) = XYZ(J2,1)
      CJ(1,3) = XYZ(J3,1)
      EJ(I,1) - FUL(JI,I)
      EJ(I,2) = FUL(J2,I)
      EJ(I,3) = EUL(J3,I)
      IVI(I) = JDOF(JI,I)
      IV1(I+3) = JDCF(J2,1)
   40 \text{ IVI}(I+6) = JDCF(J3,I)
      IF (LP .EG. 1) GO TO 50
C
      DC 42 I=1.3
      CJ(I,4) = XYZ(J4,1)
      EJ(I,4) = EUL(J4,I)
   42 \text{ IV}(I+9) = JDOF(J4,I)
C
```

```
50 G = SQRT(GV(1)**2 + GV(2)**2 + GV(3)**2)
      DO 51 I=1.3
   51 \text{ EV(I)} = -\text{GV(I)/G}
       DO 52 L-1.LR
      CALL KGRAV (CJ,JM(1,L),EV,A,W,KW,KCJM)
C
      DO 53 I=1,3
      JN0 = JM(I,L)
      L1 = 3*1 - 2
      IVTRI(L1) = 3*JNO - 2
      IVTRI(L1+1) = 3*JN0 - 1
   53 IVTRI(L1+2) = 3*JNC
      SS = RD*G*A/24.
      IF (LR .GT. 1) SS = SS/2.
   52 CALL REVADD (SS,W,IVTRI,IVTRI,S,9,9,NCOL,NCOL,KW,KW)
C
      DO 65 J=1.NJN
      J1 = 3*J - 2
   65 CALL EULEF (FJ(1,J),T(J1,J1),KW)
      CALL ETABA . (S,T,NCCL,NCOL,KW,KW)
C
                               .CR. NAMEK .EQ. 6HNOSTIF) GO TO 20
      IF (NAMEK .EQ. 6H
                                                             NERRCR=2
      IF (NUTKY .LE. 0) GC TU 999
      WRITE (NUTKX) NAMEK, NFL, NCOL, NCOL, NAMEL, (IBLNK, I=1,5),
          ((S(I,J),I=1,NCOL),J=1,NCOL), (IV1(I),I=1,NCOL)
C
      GD TD 20
C
  999 CALL ZZBOMP (6HGRAVTY, NERROR)
      END
```

```
SUBROUTINE KIAI (Al, A2, RL, E, Z, TS, KZ, KTS)
      DIMENSION Z(KZ,1), TS(KTS,1)
C
   SUBROUTINE TO CALCULATE FINITE ELEMENT ...
C
      STIFFNESS MATRIX.
C
      STRESS TRANSFORMATION MATRIX.
   FOR AN AXIAL FOD ELEMENT WITH UNRESTRAINED BOUNDARIES.
   ROD MAY BE LINEARLY TAPERED OR UNIFORM.
   CONSTANT FORCE ASSUMED.
   STIFFNESS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C
   STRESS TRANSFORMATION MATRIX RELATES STRESS AT ROD ENDS IN LOCAL
C
C
   COCRDINATE SYSTEM TO DEFLECTIONS IN LOCAL COORDINATE SYSTEM.
C
   ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
      SIGMA-X1, SIGMA-X2
C
C
   WHERE SIGMA IS NORMAL STRESS.
C
   SX1(-), SX2(+) IS TENSION. SX1(+), SX2(-) IS COMPRESSION.
   THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
C
C
   WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C
   LOCAL COORDINATE ORDER IS
C
      DX1,DX2
C
   WHERE DX IS TRANSLATION.
C
   DEVELOPED BY PL WOHLEN. SEPTEMBER 1972.
C
   LAST REVISION BY RL WOHLEN. SEPTEMBER 1973.
C
      SUBROUTINE ARGUMENTS
C
C
   A1 = INPUT CROSS-SECTION AREA AT ROD END 1.
C
   A2 = INPUT CROSS-SECTION AREA AT ROD END 2.
   RL = INPUT ROD LENGTH.
C
       = INPUT YOUNGS MODULUS OF ELASTICITY.
C
       = CUTPUT STIFFNESS MATRIX. SIZE(2,2).
C
   TS = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(2,2).
C
   KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
C
   KTS = INPUT FOW DIMENSION OF TS IN CALLING PROGRAM. MIN=2.
C
      S = A1*E/RL
      R = A2/A1
      IF (ABS(R-1.) \cdot GT. \cdot O1) S = (A2-A1)*E / (RL*ALOG(R))
   STIFFNESS MATRIX.
      Z(1,1) = 5
      Z(1,2) = -5
      Z(2,1) =-5
      Z(2,2) = S
   STRESS TRANSFORMATION MATRIX.
      TS(1,1) = Z(1,1)/A1
      TS(1,2) = Z(1,2)/A1
      TS(2,1) = 2(2,1)/A2
      TS(2,2) = 2(2,2)/A2
C
      RETURN
      END
```

```
DIMENSION Z(KZ,1), TS(KTS,1)
      DATA EPS/1.E-15/
C
C
   SUBROUTINE TO CALCULATE FINITE ELEMENT ...
      STIFFNESS MATRIX.
      STRESS TRANSFORMATION MATRIX.
   FOR A BENDING (PLUS SHEAR) PEAM ELEMENT WITH UNRESTRAINED BOUNDARIES.
   BEAM MAY BE LINEARLY TAPERED OR UNIFORM.
   UNIFORM SHEAR AND LINEAR BENDING MOMENT VARIATION IS ASSUMED.
   SHEAR STIFFNESS USES SF*A1*G AND SF*A2*G. IF ANY OF THESE VARIABLES
   ARE ZERO, THERE IS NO SHEAR DEFORMATION IN BENDING. STIFFNESS MATRIX IS IN LOCAL COORDINATE SYSTEM.
   STRESS TRANSFORMATION MATRIX RELATES STRESS AT BEAM ENDS IN LOCAL
   COORDINATE SYSTEM TO DEFLECTIONS IN LOCAL COORDINATE SYSTEM.
   ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C
      TAU-X1, TAU-X2, SIGMA-X1, SIGMA-X2
   WHERE SIGMA IS NORMAL STRESS (MC/I) AND TAU IS SHEAR STRESS (P/A).
C
   THE LOCAL COORDINATE SYSTEM ASSUMES THE REAM TO LIE IN THE X-Z PLANE
C
   WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C
C
   LOCAL COOPDINATE ORDER IS
C
      DZ1,DZ2,TY1,TY2
   WHERE DZ IS TRANSLATION AND TY IS ROTATION.
C
   DEVELOPED BY RL WCHLEN. FEBRUARY 1973.
C
   LAST REVISION BY RL WOHLEN. APRIL 1976.
      SUBROUTINE ARGUMENTS
C
                CROSS-SECTION AREA MOMENT OF INERTIA AT BEAM END 1.
C
   BI1 = INPUT
   BI2 = INPUT
                SAME AS BIL AT EEAM END 2.
C
C
   C1 = INPUT
                DISTANCE FROM BENDING NEUTRAL AXIS TO OUTER FIBER
                 AT BEAM END 1.
C
      = INPUT
                 SAME AS C1 AT BEAM END 2.
C
   C2
C
      = INPUT
                CROSS-SECTION AREA AT BEAM END 1. CAN BE ZERO FOR NO
   Al
C
                 SHEAR DEFORMATION IN BENDING. SHEAR STRESS IN STRESS
                 TRANSFORMATION WILL BE SET TO ZERO.
C
C
       = INPUT
                SAME AS A1 AT BEAM END 2.
  A2
                 SHAPE FACTOR (K) FOR SHEAR IN KAG.
C
   SF
      = INPUT
C
                USE SF=0.0 FOR NO SHEAR DEFORMATION IN BENDING.
C
                 SF=1.0 FOR A SOLID CIRCULAR CYLINDER.
C
                 SF=.5 FCR A THIN WALLED CIRCULAR CYLINDER.
      = INPUT
                ROD LENGTH.
C
   RL
                YOUNGS MODULUS OF ELASTICITY.
C
   Ε
       = INPUT
C
       = INPUT
                SHEAR MODULUS OF FLASTICITY. CAN BE ZERO FOR NO SHEAR
   G
                DEFORMATION IN LENDING.
C
       = CUTPUT STIFFNESS MATRIX. SIZE(4,4).
C
   2
      = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(4,4).
C
   TS
C
       = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=4.
   ΚZ
C
   KTS = INPUT ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=4.
   BENDING FLEXIBILITY.
      PPI = FI2/FI1
      REIM1 = PFI-1.
      IF (ABS(RBIM1) .LT. .01) GO TO 15
      EPS = ExEII*PLIM1
      REILN = ALCG(RPI)
```

(BI1, EI2, C1, C2, A1, A2, SF, RL, E, G, Z, TS, KZ, KTS)

SUBROUTINE KIEL

```
F11 = (.5 - 1./RBIM1 + RBILN/RBIM1**2) * (RL**3) / EBR
      F12 = (1. - RBILN/RBIM1) * (RL**2) / EBR
      F22 = RL* RPILN / EER
      GC TO 20
   15 F11 = RL**3 / (3.*E*BI1)
      F12 = PL**2 / (2.*E*BI1)
      F22 = RL/(E*RII)
C SHEAR FLEXIBILITY.
   20 IF (SF.LT.EPS .OR. A1.LT.EPS .OR. A2.LT.EPS .OR. G.LT.EPS)GO TO 30
      RA = A2/A1
                                                                          <u>:</u>-
      IF (ABS(RA-1.) .LT. .01) GO TO 25
      F11 = F11 + RL * ALOG(RA) / (SF*G*(A2-A1))
      GC TC 30
   25 F11 = F11 + RL/(SF*A1*G)
C
   BENDING + SHEAR STIFFNESS MATRIX.
   30 D = F11*F22 - F12**2
      Z(1,1) = F22/D
      Z(1,2) = -Z(1,1)
      Z(1,3) = -F12/D
      Z(1,4) = (-RL*F22 + F12)/D
      Z(2,2) = Z(1,1)
      Z(2,3) = -Z(1,3)
      Z(2,4) = -Z(1,4)
      \lambda(3,3) = F11/D
      Z(3,4) = (RL*F12 - F11)/D
      Z(4,4) = (F22*RL**2 - 2.*RL*F12 + F11)/D
   SYMMETRIZE LOWER HALF.
      DC 40 J=1,4
      DO 40 I=J,4
   40 \ Z(I,J) = Z(J,I)
C
   STRESS TRANSFORMATION MATRIX.
C
      DO 55 J=1,4
      TS(1,J) = 0.0
      TS(2,J) = C.0
      IF (A1 .GT. 0.0) TS(1,J) = Z(1,J)/A1
      IF (A2 \cdot GT \cdot 0 \cdot 0) TS(2 \cdot J) = Z(2 \cdot J)/A2
      TS(3,J) = 2(3,J)*C1/BI1
   55 \text{ TS}(4,J) = Z(4,J)*C2/B12
C
      RETURN
      END
```

```
SUBROUTINE K1C1 (TJ1,TJ2,R1,R2,RL,G,Z,TS,KZ,KTS)
      DIMENSION Z(KZ,1), TS(KTS,1)
   SUBROUTINE TO CALCULATE FINITE ELEMENT...
      STIFFNESS MATRIX,
      STRESS TRANSFORMATION MATRIX,
   FOR A TORSION ROD ELEMENT WITH UNRESTRAINED BOUNDARIES.
   RUD MAY BE LINEARLY TAPERED OR UNIFORM.
   CONSTANT TORQUE ASSUMED.
   STIFFNESS MATRIX IS IN LOCAL COORDINATE SYSTEM.
   STRESS TRANSFORMATION MATRIX PELATES STRESS AT ROD ENDS IN LOCAL
   COORDINATE SYSTEM TO ROTATIONS IN LOCAL COORDINATE SYSTEM.
   ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
      TAU-X1, TAU-X2
C
   WHERE TAU IS SHEAR STRESS.
   STRESS IS + CR - AS RIGHT HAND AXIS BETWEEN END PLINTS 1 AND 2.
   THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
C.
   WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C
   LOCAL COORDINATE ORDER IS
C
      TX1,TX2
C
   WHERE TX IS ROTATION.
C
   DEVELOPED BY RL WOHLEN. FEBRUARY 1973.
   LAST REVISION BY RL WOHLEN. SEPTEMBER 1973.
C
      SUBROUTINE ARGUMENTS
                CROSS-SECTION SAINT VENANTS TORSION CONSTANT (J) IN JG
   TJ1 = INPUT
                AT ROD END 1. E.G., TJ1=.5*PI*R1**4 FOR A SOLID CIRCULAR
C
                CYLINDER. TJ1=2.*PI*T*R1**3 FOR A THIN WALLED CIRCULAR
C
                CYLINDER.
                CROSS-SECTION SAINT VENANTS TORSION CONSTANT (J) IN JG
C
   TJ2 = INPUT
C.
                AT ROD END 2.
C
   R1
      = INPUT
               DISTANCE FROM TORSION AXIS TO OUTER FIBER AT ROD END 1.
C
               DISTANCE FROM TORSION AXIS TO OUTER FIBER AT ROD END 2.
      = INPUT
   Ŕ2
                ROD LENGTH.
      = INPUT
   RL
                SHEAR MODULUS OF ELASTICITY.
       = INPUT
       = CUTPUT STIFFNESS MATRIX. SIZE(2,2).
      = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(2,2).
   TS
      = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
C
   ΚZ
   KTS = INPUT ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=2.
C
C
      S = TJ1*G/RL
      R = TJ2/TJ1
      IF (ABS(R-1.) \cdot GT. \cdot O1) S = (TJ2-TJ1)*G / (RL*ALOG(R))
   STIFFNESS MATRIX.
      Z(1,1) = S
      Z(1,2) = -S
      Z(2,1) = -5
      Z(2,2) = 5
   STRESS TRANSFORMATION MATRIX.
      TS(1,1) = Z(1,1)*F1/TJ1
      TS(1,2) = Z(1,2)*R1/TJ1
      TS(2,1) = Z(2,1)*R2/TJ2
      TS(2,2) = Z(2,2)*R2/TJ2
C
```

RETURN END

```
DIMENSION Z(KZ,1),T(KT,1),R(KR,1)
      DIMENSION XE(3), ET(3)
   SUBROUTINE TO CALCULATE FINITE ELEMENT ...
C
      STIFFNESS MATRIX.
C
      STRESS TRANSFORMATION MATRIX.
C
   FOR A MEMBRANE TRIANGLE PLATE ELEMENT WITH UNRESTRAINED BOUNDARIES.
   QUADRATIC DISPLACEMENT (LINEAR STRAIN) FIELD IS USED.
   STIFFNESS MATRIX IS IN LOCAL COORDINATE SYSTEM.
   STRESS TRANSFORMATION MATRIX RELATES STRESS AT TRIANGLE VERTICES
C
   IN LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE LOCAL SYSTEM.
C
   ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C
C
      (SIGMA-X, SIGMA-Y, TAU-XY) JOINT 1, THEN JOINT 2, 3.
   WHERE SIGMA IS NORMAL STRESS AND TAU IS SHEAR STRESS.
   THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLANE
C
C
   WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
C
   X AXIS, AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
C
   LOCAL COORDINATE ORDER IS
C
      (DX,DY,TZ) JOINT 1, THEN JOINT 2, 3.
C
   WHERE DX, DY ARE TRANSLATION, AND TZ IS ROTATION.
C
   CALLS FORMA SUBROUTINES BTABA AND MULTA.
C
   DEVELOPED BY CS BODLEY, WA BENFIELD. MARCH 1973.
C
   LAST REVISION BY CS BODLEY. SEPTEMBER 1973.
C
C
      SUBROUTINE ARGUMENTS
C
                   LOCAL X COORDINATE LOCATION OF JOINT 2.
   X2
          = INPUT
C
   X3
          = INPUT
                   LOCAL X COORDINATE LOCATION OF JOINT 3.
C
   Y3
          = INPUT
                   LOCAL Y COCRDINATE LOCATION OF JOINT 3.
C
   TH
          = INPUT
                   PLATE THICKNESS.
                   YOUNGS MODULUS OF ELASTICITY.
C
   E
          = INPUT
C
   ANU
          = IMPUT POISSONS RATIC. (E/2G)-1.
C
          = OUTPUT STIFFNESS MATRIX. SIZE (9,7).
   7
C
          = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(9,9).
   T
C
                   MATRIX WORK SPACE. SIZE(8,9).
          = INPUT
                   ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=9.
C
          = INPUT
   ΚZ
                   ROW DIMENSION OF T IN CALLING PROGRAM. MIN=9.
C
          = INPUT
   KT
                   POW DIMENSION OF R IN CALLING PROGRAM. MIN=8.
C
          = INPUT
   KR
C
      DO 5 I=1,9
      D0.5 J=1,9
    5 T(I,J) = 0.0
      DO 10 I=1,9
      DC 10 J=1.9
   10 Z(I,J) = 0.0
      IF (TH .LF. 0.0) RETURN
      X22 = X2*X2
      Y32 = Y3*Y3
      X2Y3 = X2*Y3
      SE1 = X3/X2
      G = E/(2. + 2.*ANU)
      DD = E*TH/(1. - \Lambda NU**2)
      DNU = DD*ANU
      DG = G*TH
```

C

SUBROUTINE K2A1 (X2,X3,Y3,TH,E,ANU,Z,T,P,KZ,KT,KR)

```
DO 15 I=1,8
      DC 15 J=1.9
   15 R(I,J) = 0.
C
      F00 = X2Y3/2.
      F10 = X2Y3*(1. + SE1)/6.
      F01 = X2Y3/6.
      F20 = X2Y3*(1. + SE1 + SE1**2)/12.
      F11 = X2Y3*(1. + 2.*SE1)/24.
      F02 = X2Y3/12.
C
      Z(1,1) = DD*F00/X22
      Z(1,3) = DD * FO1/X22
      Z(1,6) = DNU*F00/X2Y3
      Z(1,8) = DNU*F10/X2Y3
      Z(2,2) = DG*F00/Y32
      Z(2,3) = DG*F10/Y32
      Z(2,4) = 2.*DG*F01/Y32
      Z(2,5) = DG*F00/X2Y3
      Z(2,7) = 2.*DG*F10/X2Y3
      Z(2,8) = DG*F01/X2Y3
      Z(3,3) = DD*F02/X22 + DG*F20/Y32
      Z(3,4) = 2.*DG*F11/Y32
      Z(3,5) = DG*F10/X2Y3
      Z(3,6) = DNU + F01/X2Y3
      Z(3,7) = 2.*DG*F20/X2Y3
      Z(3,8) = DNU*F11/X2Y3 + DG*F11/X2Y3
      Z(4,4) = 4.*UG*F02/Y32
      Z(4,5) = 2.*DG*F01/X2Y3
      Z(4,7) = 4.*DG*F11/X2Y3
      Z(4,8) = 2.*DG*F02/X2Y3
      Z(5,5) = DG*F00/X22
      Z(5,7) = 2.*DG*F10/X22
      Z(5,8) = DG*F01/X22
      Z(6,6) = DD*F00/Y32
      Z(6,8) = DD*F10/Y32
      Z(7,7) = 4.*DG*F20/X22
      Z(7,8) = 2.*DG*F11/X22
      Z(8,8) = DD*F20/Y32 + DG*F02/X22
      DC 20 I=1,8
      DO 20 J=I,8
   20 Z(J,I) = Z(I,J)
C
      R(1,1) = -1.
      R(1,c) = 1.
      R(2,1) = SE1 - 1.
      F(2,3) = -Y3
      R(2,4) = -5F1
      R(2,7) = 1.
      R(2,9) = Y3
      R(3,3) = Y2
      R(3,6) = -43
      R(4,3) = Y3*(1. - SE1)
      R(4,6) = Y3*SE1
      R(4,9) = -43
```

```
R(5,2) = -1.
     R(5,3) = X2
     R(5,5) = 1.
      R(5,6) = -x2
     R(6,2) = SE1 - 1.
     R(6.5) = -SE1 -
      R(6,6) = x3
      R(6,8) = 1.
      R(6,9) = -X3
      R(7,3) = -X2
      R(7,6) = X2
      P(8,3) = X2*(SE1 ~ 1.)
      R(5,0) = -X3
      R(8,9) = X2
C
      CALL BTABA (Z,R,8,9,KZ,KR)
C
     DII = DO/TH
     D12 = ANU*D11
      033 = G
      XE(1) = 0.
      XE(2) = 1.
      XF(3) = SF1
      ET(1) = 0.
      ET(2) = 0.
      ET(3) = 1.
      DO 30 I=1,3
      K1 = 3*I - 2
     K2 = K1 + 1
      K3 = K1 + 2
      T(K1,1) = D11/X2
      T(K1,3) = D11*ET(1)/X2
      T(K1,6) = D12/Y3
      T(K1,8) = D12*XE(1)/Y3
      T(K2,1) = D12/X2
      T(K2,3) = D12*ET(I)/X2
      T(K2,6) = D11/Y3
      T(K2,8) = D11\pi XE(I)/Y3
      T(K3,2) = D33/Y3
      T(K3,3) = D33*XF(1)/Y3
      T(K3,4) = 2.*D33*5T(I)/Y3
      T(K3,5) = D33/X2
      T(K3,7) = 2.*D33*XE(1)/X2
   30 T(K3,8) = -1*ET(1)/X2
      CALL MULT. (T,R,9,8,9,KT,KR)
C
      RETURN
      END
```

```
DIMENSION Z(KZ, 1), TS(KTS, 1), T(KT, 1)
      DIMENSION R(10,10), IVEC(10), CCEF(9), XE(3), ET(3)
C
   SUBROUTINE TO CALCULATE FINITE ELEMENT ...
C
      STIFFNESS MATRIX,
      STRESS TRANSFORMATION MATRIX.
   FOR A BENDING TRIANGLE PLATE ELEMENT WITH UNPESTRAINED BOUNDARIES.
   CUBIC DISPLACEMENT (LINEAR CURVATURE) FIELD IS USED.
   STIFFNESS MATRIX IS IN LOCAL COOPDINATE SYSTEM.
   STRESS TRANSFORMATION NATRIX RELATES STRESS AT JOINTS IN LOCAL
   COORDINATE SYSTEM TO DEFLECTIONS IN THE LOCAL SYSTEM.
C
   ROW OFFER IN STRESS TRANSFORMATION MATRIX IS
C
      'SIGMA-X, SIGMA-Y, TAU-XY) FOR (Z=TH/2) AT JOINT 1, THEN JOINT 2,3,
C.
      (SIGMA-X, SIGMA-Y, TAU-XY) FOP (Z=-TH/2) AT JOINT 1, THEN JOINT 2,3.
Ĉ
   WHERE SIGMA IS NORMAL STRESS AND TAU IS SHEAR STRESS.
C
   THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLANE
   WITH JOINT 1 AT THE X-Y URIGIN, JOINT 2 LIES ALONG THE POSITIVE
C
   X AXIS, AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
   LOCAL COMPDINATE OFDER 15
C
      (DZ,TX,TY) JOINT 1, THEN JOINT 2, 3.
   WHERE DZ IS TRANSLATION AND TX, TY ARE ECTATIONS.
C
   CALLS FORMA SUFFICIENTINES PTABA AND MULTA.
   DEVELOPED BY CS ECOLEY. MARCH 1973.
   LAST PEVISION BY CS EDDLEY. SEPTEMBER 1973.
C
C
      SUBREUTINE ARGUMENTS
C
  X 2
          = INPUT LCCAL X COORDINATE LOCATION OF JOINT 2.
                   LOCAL X COORDINATE LOCATION OF JOINT 3.
C
  X3
          = INPUT
C
          = INPUT
                  LCCAL Y COURDINATE LOCATION OF JOINT 3.
  Y3
C
          = INPUT PLATE THICKNESS.
   TH
                  YOUNGS MODULUS OF ELASTICITY.
C
          = IMPUT
  Έ
C
          = INPUT PCISSONS RATIO. (E/2G)-1.
  ANU
C
  Z
          = CUTPUT STIFFNESS MATRIX. SIZE (9,9).
          = CUTPUT L'CAL STRESS TRAMSFORMATION MATRIX. SIZE(18,9).
C
  TS
C
   T
          = INPUT MATRIX WERK SP. CE. SIZE(10,10).
                  FOW DIMENSION OF Z IN CALLING PROGRAM. MIN=9.
C
   ΚZ
          = INPUT
                  POW DIMENSION OF TS IN CALLING PROGRAM. MIN=18.
C
   KT5
          = INPUT
          = INPUT ROW DIMENSION OF T IN CALLING PROGRAM. MIN=10.
C
   KT
C
      DC 16 I=1,9
      00 10 J=1,9
   10 \ Z(I,J) = 0.0
      DO 11 I=1,18
      DC 11 J=1,0
   11 TS(I,J) = 6.0
      IF (TH .LF. 0.0) FETURN
C
      DO 12 I=1,10
      DC 12 J=1.10
   12 T(1,J) = 6.0
      X22 = X2*X2
      X24 = X22*X22
      Y32 = Y3*Y3
      Y34 = Y32*Y32
```

SUBBOUTINE K2E1 (X2,X3,Y3,Th,E,ANU,Z,TS,T,KZ,KTS,KT)

```
SE1 = X3/X2
      SE2 = SE1*SE1
      SE3 = S52 + SE1
      SEA = SE3*SE1
      SEC1 = (1. + SE1)/3.
      SEC2 = SEC1**2
      SEC3 = SEC1**3
      G = E/(2. + 2.*ANU)
      DD = (E+T+++3)/(12.+(1.-ANU++2))
      DNU = DD*ANU
      DG = (G*TH**3)/12.
      AL = DD/XI
      BE = DNU/(x22 + Y32)
      GA = CD/Y34
      DE = 4.*DG/(X22*Y32)
C
      T(1,1) = 1.
      T(2.3) = 1.
      T(3,2) = 1.
      T(4,1) = 1.
      T(4,2) = 1.
      T(4,4) = 1.
      T(4,7) = 1.
      T(5,3) = 1.
      T(5,5) = 1.
      T(5,8) = 1.
      T(6,2) = 1.
      T(6,4) = 2.
      T(6,7) = 3.
      T(?,1) = 1.
      T(7,2) = SF1
      T(7,3) = 1.
      T(7,4) = 5^{2}
      T(7,5) = SE1
      T(7,6) = 1.
      T(7,7) = SE3
      7(7,8) = 562
      T(7,9) = SEI
      T(7,10) = 1.
      T(8,3) = 1.
      T(8,5) = SEI
      T(8,6) = 2.
      T(8,8) = 562
      T(8,9) = 2.*SEI
      T(8,10) = 3.
      T(9,2) = 1.
      T(9,4) = 2.*SE1
      T(9,5) = 1.
      T(9,7) = 3.*SF2
      T(0,E) = 2.*5E1
      T(9,9) = 1.
      T(10,1) = 1.
      T(10,2) = SEC1
      T(10.3) = 1./3.
      T(10,4) = SFC2
```

```
T(10,5) = SEC1/3.
      T(10,6) = 1./9.
      T(10,7) = 5603
      T(10.8) = SEC2/3.
      T(10,9) = SE(1/9.
      T(10,10) = 1./27.
C
      DO 5 1=1,10
      DO 7 J=1,10
    7 R(I,J) = 0.
    5 R(I,I) = 1.
C
      DC 160 L=1.10
      JEIG = 1
      A1 = AES(T(L,1))
      DC 15 J=2+10
      A2 = ABS(T(L,J))
      IF (A2 .LT. A1) GO TO 15
      A1 = A2
      JEIG = J
   15 CONTINUE
      IVEC(L) = JEIG
      ALJRIG = T(L, JRIG)
      DC 17 J=1,10
      T(L,J) = T(L,J)/ALJFIG
   17 R(L,J) = F(L,J)/ALJEIG
      DO 25 I=1.10
      AljelG = T(I, JelG)
      IF (* .EC. L) GC 70 25
      DC 30 J=1,10
      T(1,J) = T(1,J) - AlJBIG*T(L,J)
   30 R(I,J) = R(I,J) - AIJPIG*R(L,J)
   25 CONTINUE
  100 CONTINUE
C
      DG 40 I=1,10
      IP = IVFC(I)
      DO 40 J=1,10
   40 T(IF,J) = R(I,J)
      DO 50 1=1.10
      DC 50 J=1,10
   50 R(I,J) = T(I,J)
C
      DC 20 I=1,10
      R(1,2) = Y3*F(1,2)
      R(1,3) = -x2*F(1,2)
      P(I,5) =
               Y3#F(I,F)
      R(1,6) = -X2*^{2}(1,6)
      P(I,8) = Y3*F(I,8)
   20 R(I,9) = -X2*9(I,9)
C
      CCEF(1) = 1./2.
      CCEF(2) = Y2/18.
      CDEF(3) = -(x_2+x_3)/16.
      CDEF(4) = 1.73.
```

```
CCFF(5) = Y3/18.
      CQEF(6) = (2.*X2 - X3)/18.
      CDEF(7) = 1./3.
      CDEF(8) = -Y3/9.
      COEF(9) = (2.*X3 - X2)/18.
      DO 80 I=1.10
      DO 60 J=1,9
   80 R(I,J) = R(I,J) + R(I,10) * CREF(J).
C
      DC 55 I=1.10
     00 55 J=1,10
   55 T(I,J) = 0.
C
      FOG = X2*Y3/2.
      F10 = X2*Y3*(1. + SE1)/6.
      F01 = X2*Y3/6.
      F20 = X2*Y3*(1. + SE1 + SE2)/12.
      FII = X2*Y3*(I. + 2.*SEI)/24.
      F02 = X2*Y3/12.
C
      T(4,4) = 4.*AL*FGG
      T(4,6) = 4.*EE*F00
      T(4,7) = 12.*AL*F10
      T(4,8) = 4.*AL*F01
      T(4,9) = 4.*EE*F10
      T(4,10) = 12.*EF*F01
      T(5,5) = DF*FOO
      T(5,8) = 2.*DE*F10
      T(5,9) = 2.*DE*F01
      T(6,6) = 4.*GA*FCC
      T(6,7) = 12.*EE*F10
      T(6,8) = 4.*FE*F01
      T(6,9) = 4.*GA*F10
      T(6,10) = 12.*GA*F01
      T(7,7) = 36.*AL*F20
      T(7,8) = 12.*AL*F11
      T(7,9) = 12.*FE*F20
      T(7,10) = 36.*6E*F11
      T(8,8) = 4.*AL*F02 + 4.*DF*F20
      T(8,9) = 4.*EE*F11 + 4.*DE*F11
      T(8,10) = 12.*FF*F02
      T(9,9) = 4.*GA*F20 + 4.*DE*F02
      T(9,10) = 12.*GA*F11
      T(10,10) = 36.*GA*FG2
C
      DC 60 I=1.10
      DC 60 J=I,10
   60 T(J,I) = T(I,J)
      CALL ETAFA (T.F. 10, 9, KT. 10)
      DO 85 I=1.0
      DO 85 J=1,6
   85 Z(I,J) = T(I,J)
C
      DO 73 1=1,4
      DO 73 J=1,10
```

```
73 T(I,J) = 0.0
      D11 = -6.*DD/((x2*TH)**2)
      D21 = ANU*D11
      D22 = -6.*DD/((Y3*TH)**2)
      D12 = ANU*P22
      D33 = -12.*DG/((X2*Y3)*TH**2)
      XE(1) = C.
      XE(2) = 1.
      XE(3) = SE!
      ET(1) = 0.
      ET(2) = 0.
      ET(3) = 1.
      DO 75 I=1,3
      K1 = 3 * I - 2
      K2 = K1 + 1
      K3 = K1 + 2
      T(K1,4) = 2.*011
      T(K1,6) = 2.*D12
      T(K1,7) = 6.*D11*XE(I)
      T(K1,8) = 2.*D11*ET(I)
      T(K1,9) = 2.*D12*XE(I)
      T(K1,10) = 6.*D12*ET(I)
      T(K2,4) = 2.*D21
      T(K2,6) = 2.*522
      T(K2,7) = 6.*D21*XE(I)
      T(K2,8) = 2.*D21*ET(I)
      T(K2,9) = 2.*D22*XE(1)
      T(K2(10) = 6.*022*ET(I)
      T(K3,5) = D33
      T(K3,8) = 2.*D33*\lambda E(I)
   75 T(K3,9) = 2.*D33*ET(I)
      CALL MULTA (T,R,5,10,9,KT,10)
      DO 77 I=1,9
      IP9 = I + 9
      DO 77 J=1.9
      (L,I)T = (L,I)2T
   77 TS(IPO,J) = -TS(I,J)
C
      RETURN
      END
```

SUBROUTINE K3C1 (X3, Y3, Th, G, Z, T, KZ, KT) DIMENSION Z(KZ,1), T(KT,1) SUBROUTINE TO CALCULATE FINITE ELEMENT ... C STIFFNESS MATRIX, C STRESS TRANSFORMATION MATRIX. FCR A RECTANGULAR SHEAR PANEL ELEMENT WITH UNRESTRAINED BOUNDARIES. LINEAP DISPLACEMENT (CONSTANT STRAIN) FIFLD IS USED. STIFFNESS MATRIX IS IN LOCAL COORDINATE SYSTEM. STRESS TRANSFORMATION MATRIX RELATES PANEL SHEAP STRESS (CONSTANT) IN LOCAL COOPDINATE SYSTEM TO DEFLECTIONS IN THE LOCAL SYSTEM. THE LOCAL COOPDINATE SYSTEM ASSUMES THE PANEL TO LIE IN AN X-Y PLANE WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE X AXIS, JOINT 3 IS IN THE POSITIVE X,Y DIRECTION, AND JOINT 4 LIES ALONG THE POSITIVE Y AXIS. LOCAL COORDINATE ORDER IS DX1,0X2,DX3,DY4, DY1,DY2,EY3,CY4 C WHERE DX.DY ARE TRANSLATIONS. DEVELOPED BY RL WOHLEN. APRIL 1974. C SUBROUTINE ARGUMENTS € **X**3 = INPUT LOCAL X COOPDINATE LOCATION OF JOINT 3. LCCAL Y COORDINATE LOCATION OF JOINT 3. C **Y**3 = INPLIT C TH = INPUT PANEL THICKNESS. C = INPUT SHEAR MODULUS OF ELASTICITY. G C Z = CUTPUT STIFFNESS MATRIX. SIZE(8,8). C = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(1,8). T C ΚZ = INPUT FOW DIMENSION OF Z IN CALLING PROGRAM. MIN=8. C ΚT = INPUT FOW DIMENSION OF T IN CALLING PROGRAM. MIN=1. C STIFFNESS MATRIX. C = TH\*G/4.A = C\*X3/Y3 $B = C \neq Y3/X3$ Z(1,1) = AZ(1,2) = A2(1,3) = -4Z(1,4) = -AZ(1,5) = C2(1,6) = -02(1,7) = -0Z(1,8) = 0Z(2,2) = FZ(2,3) = -AZ(2,4) = -AZ(2,5) = C $Z(2, \epsilon) = -0$ 

2(2,7) = -0 2(2,8) = 0 2(3,3) = A 2(3,4) = A 2(3,5) = -0 2(3,6) = 0 2(3,6) = 0 2(3,6) = 0 2(3,6) = 0

```
Z(4,4) = A
     Z(4,5) =-C
     2(4,6) = 0
     2(4,7) = C
     2(4,8) =-0
     2(5,5) = F
     2(5,6) = -8
     Z(5,7) =-8
     2(5,8) = 8
     Z(6,6) = F
     Z(6,7) = B
      Z(6,8) =-8
      Z(7,7) = 8
      Z(7,E) =-F
      Z(8,8) = 8
C SYMMETRIZE LOWER HALF.
      DC 10 J=1,8
DC 10 I=J,8
   10 Z(I,J) = Z(J,I)
C STRESS TRANSFORMATION MATRIX.
      DC 20 J=1.8
   20 T(1,J) = 2.*Z(3,J)/(TH*X3)
C
      RETURN
      END
```

```
SUPROUTINE KGRAV (CJ.JM
                               ,EV,A,W,KW,KCJ)
      DIMENSION CJ(KCJ ,1), JM(
                                    1), EV(1),
                                                           W(KW,1)
      DIMENSION E(3,4),R12(3),R13(3),VN(3),F(3,3)
      DATA KEF / 3 /
  SUBROUTINE TO DERIVE STIFFNESS MATRIX FOR A TRIANGULAR GRAVITY ELEMENT.
  CALLS FORMA SUPROUTINES MULTA , MULTB , VCROSS.
  DEVELOPED BY C S ECOLEY. FEBRUARY 1974.
   LAST REVISION BY C S BODLEY. NOVEMBER 1974.
C
      SUBROUTINE ARGUMENTS
C
  CJ
         = INPUT MATRIX OF JOINT COORDINATES. SIZE (3,4).
         = INPUT VECTOR OF JOINTS DEFINING A TRIANGLE. SIZE (3).
C
   JM
C
         = INPUT VECTOR NORMALIZED GRAVITY. SIZE = 3.
   E۷
         = CUTPUT AREA.
C
         = OUTPUT STIFFNESS MATRIX.
C
         = INPUT ROW DIMENSION SIZE OF W IN CALLING PROGRAM. MIN=9.
C
   KW
         = INPUT ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C
   KCJ
      J1 = JM(1)
                 )
      J2 = JM(2)
                 )
      J_2 = JM(3)
                 )
      DO 5 I=1,9
      D0.5 J=1.3
      W(I_*J) = 0.
    5 E(J,I) = 0.
      DC 7 I=1.3
      R12(I) = CJ(I,J2) - CJ(I,J1)
      R13(I) = CJ(I,J3) - CJ(I,J1)
      DC 8 J=1,3
    8 F(1.J) = 1.
    7 F(I,I) = 2.
C
      CALL VCPOSS (R12,R13, VN, VAMAG, VBMAG, A, SINAB)
      DO 10 I=1.3
   10 \text{ VN(I)} = \text{VN(I)/A}
      ACUM = 0.0
      DC 15 I=1,3
      I1 = 3*I - 3
      ACUM = ACUM + VN(I) #EV(I)
      DO 15 J=1,2
      E(I,II+J) = VN(J)
   15 W(II+J,I) = VN(J)
      CALL MULTB (F,E,3,3,9,KEF,KEF)
      CALL MULTA (W,E,9,3,9,KW,KEF)
      A = A*ACUM*ACUM*ACUM
C
      RETURN
      END
```

```
SUPROUTINE MIAI
                       (A1,A2,RL,RO,Z,KZ)
      DIMENSION 2(KZ+1)
C
   SUBROUTINE TO CALCULATE FINITE ELEMENT ...
C
C
      LUMPED MASS MATRIX
   FOR AN AXIAL FOD FLEMENT WITH UNRESTRAINED BOUNDARIES.
C
   ROD MAY BE LINEARLY TAPERED OF UNIFORM.
C
   MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C
C
   THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
C
   WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
   LOCAL COORDINATE ORDER IS
C
      DX1,DX2
C
   WHERE DX IS TRANSLATION.
C
C
   DEVELOPED BY RL WCHLEN. JANUARY 1973.
   LAST REVISION BY RL WOHLEN. SEPTEMBER 1973.
C
C
      SUBROUTINE ARGUMENTS
C
€
   A1 = INPUT CROSS-SECTION AREA AT ROD END 1.
C
   A2 = INPUT CROSS-SECTION AREA AT ROD END 2.
   RL = INPUT RCD LENGTH.
C
   RO = INPUT MASS DENSITY.
  Z = CUTPUT MASS MATRIX. SIZE(2,2).
   KZ = INPUT FOW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
C
C.
      W1 = A1 \neq RL \neq RC/6.
      W2 = A2*RL*RC/6.
      7(1,1) = 2.*W1 +
                          W2
      Z(1,2) = 0.
      2(2,1) = 0.
      Z(2,2) = W1 + 2.*W2
C
      RETURN
      END
```

```
SUBFOUTINE MIA2
                        (A1,A2,RL,R0,Z,KZ)
      DIMENSION Z(KZ.1)
C
  SUBROUTINE TO CALCULATE FINITE ELEMENT ...
C
      CONSISTENT MASS MATRIX
C
   FOR AN AXIAL FOD ELEMENT WITH UNRESTRAINED BOUNDARIES.
   ROD MAY BE LINEARLY TAPERED OF UNIFORM.
   LINEAR DISPLACEMENT FUNCTION ASSUMED.
   MASS MATRIX IS IN LOCAL COCRDINATE SYSTEM.
   THE LOCAL COOPDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
  WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C
   LOCAL COORDINATE ORDER IS
C
      DX1, DX2
  WHERE DX IS TRANSLATION.
C
   DEVELOPED BY RL WCHLEN. SEPTEMBER 1972.
   LAST REVISION BY RL WOHLEN. SEPTEMBER 1973.
C
      SUBROUTINE ARGUMENTS
              CROSS-SECTION AREA AT ROD END 1.
C
   A1 = INPUT
               CROSS-SECTION AREA AT POD END 2.
   A2 = INPUT
               ROD LENGTH.
   RL = INPUT
              MASS DENSITY.
   RO = INPUT
   Z = CUTPUT MASS MATRIX. SIZE(2,2).
C
   KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
      W1 = A1 \pm RL \pm RC/12.
      W2 = A2 \times RL \times C/12.
      2(1,1) = 3.*W1 +
                           W2
      Z(1,2) =
                  W1 +
                           W 2
      Z(2,1) = Z(1,2)
      Z(2,2) =
                  W1 + 3.*W2
C
      RETURN
      END
```

```
SUBROUTINE MIBI (A1,A2,RL,R0,Z,KZ)
     DIMENSION Z(KZ,1)
  SUBROUTINE TO CALCULATE FINITE ELEMENT ...
     LUMPED MASS MATRIX
  FOR A BENDING BEAM ELEMENT WITH UNRESTRAINED BOUNDARIES.
  BEAM MAY BE LINEARLY TAPERED OR UNIFORM.
  MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
  THE LOCAL COOPDINATE SYSTEM ASSUMES THE BEAM TO LIE IN THE X-Z PLANE
  WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
  LOCAL COURDINATE ORDER IS
     DZ1,DZ2,TY1,TY2
  WHERE DZ IS TRANSLATION AND TY IS ROTATION.
  DEVELOPED BY RL WOHLEN. FEBRUARY 1973.
  LAST REVISION BY RL WOHLUN. SEPTEMBER 1973.
      SUBROUTINE ARGUMENTS
C
  A) = INPUT CROSS-SECTION AREA AT BEAM END 1.
  A2 = INPUT
              CROSS-SECTION AREA AT BEAM END 2.
  RL = INPUT FEAM LENGTH.
  RO = INPUT MASS DENSITY.
  Z = CUTPUT MASS MATRIX. SIZE(4,4).
  KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM..MIN=4.
     W1 = A1 * PL * RO / c.
     W2 = A2*RL*RC/6.
     DO 10 J=1,4
     DO 10 I=1,4
   10 Z(I_{*}J) = 0.0
     Z(1,1) = 2.*W1 +
                         W 2
      Z(2,2) = W1 + 2.*W2
      Z(3,3) = (A1*RC*RL**3)/24.
      Z(4,4) = (A2*R8*RL**3)/24.
C
     RETURN
      END
```

```
SUBROUTINE M162
                        (A1,A2,RL,RO,Z,KZ)
      DIMENSION Z(KZ,1)
   SUBROUTINE TO CALCULATE FINITE ELEMENT ...
      CONSISTENT MASS MATRIX
   FOR A BENDING BEAM ELEMENT WITH UNRESTRAINED BOUNDARIES.
   BEAM MAY BE LINEAPLY TAPERED OR UNIFORM.
   CUBIC DISPLACEMENT FUNCTION ASSUMED.
C
   MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
   THE LOCAL COORDINATE SYSTEM ASSUMES THE BEAM TO LIE IN THE X-2 PLANE
C
   WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C
C
   LOCAL COORDINATE ORDER IS
C
      DZ1,DZ2,TY1,TY2
   WHERE DZ IS TRANSLATION AND TY IS ROTATION.
Ç
   DEVELOPED BY RL WOHLEN. FEBRUARY 1973.
C
C
   LAST REVISION BY RL WOHLEN. SEPTEMBER 1973.
C
      SUBROUTINE ARGUMENTS
C
   A1 = INPUT
              CROSS-SECTION APEA AT BEAM END 1.
   A2 = INPUT
               CRESS-SECTION AREA AT BEAM END 2.
C
   RL = INPUT
               BEAM LENGTH.
              MASS DENSITY.
C
   RO = INPUT
   Z = OUTPUT MASS MATRIX. SIZE(4,4).
C
C
   KZ = INPUT RCW DIMENSION OF Z IN CALLING PROGRAM. MIN=4.
      W1 = A1 \times RL \times RD / E40.
    . W2 = A2*RL*RC/840.
    : RL2 = RL**2
      Z(1,1) = 240.*W1 + 72.*W2
      Z(1,2) =
                 54.*W1 + 54.*W2
      Z(2,2) =
                 72.*W1 + 240.*W2
      Z(1,3) = -(30.74) +
                          14.*W2)*RL
      Z(1,4) = (14.*W1 +
                          12.*W2)*RL
      Z(2,3) = -(12.*W1 +
                          14.*W2)*RL
      Z(2,4) = (14.*W1 +
                          30-#W2)#RL
      2(3,3) = (5.*W1 +
                            3.*W2)*RL2
      Z(3,4) = -(3.*W1 +
                            3.*W2)*RL2
                          5.*W2)*RL2
      Z(4,4) = (3.*W1 +
      DO 10 J=1,4
      DO 10 I=J,4
   10 Z(I,J) = Z(J,I)
C
      RETURN
```

END

```
SUBROUTING M1C1 (PI1, PI2, RL, RO, Z, KZ)
   * DIMENSION Z(KZ,1)
   SUBROUTINE TO CALCULATE FINITE ELEMENT ...
C
      LUMPED MASS MATRIX
C
   FOR A TURSION ROD ELEMENT WITH UNRESTRAINED BUUNDARIES.
   ROD MAY BE LINEARLY TAPERED OR UNIFORM.
   MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
C
   THE LOCAL COORDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
C
   WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
C
   LOCAL COORDINATE ORDER IS
C
      TX1,TX2
C
   WHERE TX IS ROTATION.
C
   DEVELOPED BY RL WOHLEN. FEBRUARY 1973.
C
   LAST REVISION BY RL WOHLEN. SEPTEMBER 1973.
      SUBROUTINE ARGUMENTS
C
C
   PII = INPUT CROSS-SECTION POLAR AREA MOMENT OF INERTIA AT ROD END 1.
C
   PI2 = INPUT
               CROSS-SECTION POLAR AREA MOMENT OF INERTIA AT ROD END 2.
               FOD LENGTH.
C
   RL = 1NPUT
C
   RO = INPUT MASS DENSITY.
C
      = CUTPUT MASS MATRIX. SIZE(2,2).
   2
C
   KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
      W1 = PI1*PL*RD/6.
      W2 = PI2*RL*RC/6.
      Z(1,1) = 2.*W_{\perp} +
                          W 2
      Z(1,2) = 0.
      Z(2,1) = 0.0
      Z(2,2) = W1 + 2.*W2
C
      RETURN
      END
```

```
SUBROUTING MICE (PII, PI2, RL, RO, Z, KZ)
      DIMENSION Z(KZ,1)
C
C
  SUBROUTINE TO CALCULATE FINITE ELEMENT...
     CONSISTENT MASS MATRIX
C
 FOR A TORSION FOD ELEMENT WITH UNRESTRAINED BOUNDARIES.
  ROD MAY EF LINEARLY TAPERFO OR UNIFORM.
  LINEAR DISPLACEMENT FUNCTION ASSUMED.
  MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
  THE LOCAL COOPDINATE SYSTEM ASSUMES THE ROD TO LIE ALONG THE X AXIS
  WITH JOINT 1 AT THE ORIGIN, JOINT 2 ALONG THE POSITIVE X AXIS.
  LOCAL COORDINATE OFFER IS
C
      TX1.TX2
  WHERE IX IS ROTATION.
  DEVELOPED BY RL WOHLEN. FEBRUARY 1973.
  LAST REVISION BY BL WOHLEN. SEPTEMBER 1973.
C
C.
C
      * UBROUTINE ARGUMENTS
   PIL = INPUT CROSS-SECTION POLAR AREA MOMENT OF INERTIA AT ROD END 1.
  PI2 = INPUT CROSS-SECTION POLAR AREA MOMENT OF INERTIA AT ROD END 2.
      = INPUT ROD LENGTH.
   RL
   RU = INPUT MASS DENSITY.
       = CUTPUT MASS MATRIX. SIZE (2,2).
   KZ = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=2.
      W1 = PI1*P' *F0/12.
      W2 = PI2*FL*RO/12.
      Z(1,1) = 3.*W1 +
                          W 2
               W1 +
      Z(1,2) =
                          W2
      2(2,1) = 2(1,2)
                W1 + 3. *W2
      Z(2,2) =
C
      RETURN
      END
```

```
SUPPOUTINE M241 (X25Y3, TH-RC,Z-KZ)
      DIMENSION Z(KZ,1)
C
. C
    SUBROUTINE TO CALCULATE FINITE ELEMENT ...
      LUMPED MASS MAT IX,
-C
    FOR A MEMBRANE TRIANGLE PLATE ELEMENT WITH UNRESTRAINED BOUNDARIES.
    MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
   THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLANE
   WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
   X AXIS. AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
    LOCAL COCHDINATE OFFICE IS
       (DX,DY,TZ) JOINT 1, THEN JOINT 2, 3.
  WHERE DX. DY ARE TRANSLATIONS AND TZ IS LOTATION.
 C
    DEVELOPED BY WA BENFIELD. FEERUARY 1973.
C
C
    LAST REVISION BY AL WOHLEN. SEPTEMBER 1973.
C
C
       SUBROUTINE ARGUMENTS
         TE INPUT LOCAL X COORDINATE LOCATION OF JOINT 2.
C
   X 2
           = INPUT LCCAL Y CCORDINATE LOCATION OF JOINT 3.
C
   Y3
           = INPUT PLATE THICKNESS.
C
   TF
  RC
           = INPUT MASS DENSITY.
C
 C
  Z
           = CUTPUT MASS MATRIX. SIZE(9.9).
\mathbf{C} = \mathbf{KZ}
           = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=9.:
 C
       AREA = 0.5#\2#Y3
      CM = (RO*TH*ARFA)/3.0
      DC 1C I=1,c
      00 10 J=1,c
    10 \ Z(I_{\bullet}J) = C_{\bullet}C
      DC 20 I=1,0
    20 \cdot 2(1,1) = CM
       RETURN
       END
```

SUPPOUTING MEAS (X2,X3,Y3,TH,PHC,Z,T,R,KZ,KT,KR) DIMENSION  $\lambda(KZ,1),T(KT,1),F(KR,1)$ C SUBROUTINE TO CALCULATE FINITE ELEMENT... CONSISTENT MASS MATRIX. FOR A MEMERANE TRIANGLE PLATE ELEMENT WITH UNRESTRAINED BOUNDARIES. QUADRATIC DISPLACEMENT (LINEAR STRAIN) FIELD IS USED. MASS MATRIX IS IN LOCAL COERDINATE SYSTEM. THE LOCAL COORDINATE SYSTEM AS THE PLATE TO LIE IN AN X-Y PLANE WITH JOINT 1 AT THE X-Y OFIGIN, JOINT 2 LIES ALONG THE POSITIVE X AXIS, AND JOIN! 3 IS IN THE POSITIVE Y DIRECTION. LOCAL COORDINATE PROBER IS (DX,DY,TZ) JOINT 1, THEN JOINT 2, 3. WHERE DX, DY ARE TRANSLATIONS AND TZ IS ROTATION. CALLS FORMA SUBROUTINES BTABA. DEVELOPED BY CS SCOLEY. MARCH 1973. LAST REVISION BY WA BENFIELD. SEPTEMBER 1973. SUBROUTINE ARGUMENTS = INPUT LOCAL X COORDINATE LOCATION OF JOINT 2. X2 LCCAL X COCEDINATE LOCATION OF JOINT 3. **X3** - INPUT LOCAL Y COOFDINATE LOCATION OF JOINT 3. FLATE THICKNESS. **Y3** = INPUT TH = INPUT = INPUT MASS DENSITY. RHC = CUTPUT MASS MATRIX. SIZE(9,9). Z MATE IX WORK SPACE. SIZE(10,10). T = INPN MATRIX MORK SPACE. SIZE(10,10). Ŕ = INPUT = INPUT FOW DIMENSION OF Z IN CALLING PROGRAM. MIN=9. ΚZ KT = INPUT RCW TIMENSION OF To IN CALLING PROGRAM. MIN=10. KR = INPUT ROW DIMENSION OF R IN CALLING PROGRAM. MIN=10.: SE! = X3/X2SE2 = SE1\*SE1 SE3 = SE7 \* SE1SE4 = SE3#SE1 X2Y3 = X2\*Y3\*FH0\*TH · DC 10 I=1,16 DO 10 J=1,10

C

C

C

C

C

C

C

C

C

C

C C

C

C

C

C

C

C

C

C

C

C

C

C

C

. C

C

T(I,J) = 0.

10 R(1,J) = 0.FOC = 9293/2. F1C = X2Y2\*(1. + SE1)/6.FG1 = X2Y3/6.F2G = X2Y3\*(1. + 5E1 + 5E2)/12.F11 = X2Y3\*(1. + 2.\*5E1)/24.F02 = X2Y3/12. $F30 = X2Y3*{1. + SE1 + SE2 + SE31/20.}$ F21 = X2Y3\*(1. + 2.\*SE1 + 3.\*SE2)/60.F12 = X2Y3\*(1. + :2.\*SE1)/60.FG2 = X2Y3/20. $F4C = \frac{9293*11.}{51.} + \frac{51}{51.} + \frac{51$ F31 = X2Y3\*(1. + 2.\*5F] + 3.\*5F2 + 4.\*5F3]/120. F22 = X2Y3\*(1. + 3.\*SE1 + 6.\*SE2)/180.

```
-F13 = X2Y3*(1. + 4.*SE1)/120.
    F04 = X2Y3/30.
     T(1,1) = FCC
     T(1,2) = F10
      (7(1,3) = F01)
    ^{2}(1,4) = F11
     T(1,5) = F02
      T(2,2) = F20
      T(2,3) = F11
     T(2,4) = F21
      T(2,5) = F12
      T(3,3) = F02
      T(3,4) = F12
      T(3,5) = F63
      T(4,4) = F22
      T(4,5) = F13
      T(5,5) = F(4)
      T(6,6) = F(0)
      T(6,7) = F10
     F(6,8) = F01
      T(6,9) = F20
      T(6,10) = F11
      T(7,7) = F20
      T(7,8) = F11
      T(7,9) = F20
      T(7,16) = F21
      T(8,8) = F(2)
      T(9,9) = F21
      T(E,10) = F12
      T(0,0) = F4(
      T(9,10) = F31
      T(10,10) = F22
      DO 20 1=1,10
      DO 30 J=I.10 2
   30 T(J_{+}L) = T(L_{+}J_{-})
C
      F(1,1) = 1.
      R\{2,1\} = -1.
      R\{2,4\} = 1.
     -P(3,1) = S(1 - 1.
      K(3,3) = -43
      F(7,4) = -SE1
      P(3,7) = 1.
      R(3,9) = Y_3
     $ (4,3) = Y3
      R(4,6) = -Y3
      R(5,3) = Y3*(1. - SF1)
      P(5,6) = Y2*SE1
      P(5,0) = -Y3
      R(6,2) = 1.
      F(7,2) = -1.
      F(7,3) = y2
      P(7,5) = 1.
      R(7,6) = -y_2
      R(8,2) = SEI - 1.
```

```
R(8,5) = -561 -
      *(8,6) = X3
      R(8,8) = 1.
      F(9,9) = -y_3
      R(4,3) = -x2
      F(0,6) = X2
      F(10,2) = X2*(SE1 - 1.)

F(10,6) = -X3

F(10,9) = X2
     R(10.9) = X2
C
      CALL PTAEA (T.R., 10,9, KT., KR)
      PC 40 I=1,0
      DC 40 J=1,0
   40 Z(I,J) = T(I,J)
C
   C RETURN
      END
```

```
SUBROUTINE M281 (X2,Y3,TH,R0,Z,KZ)
      DIMENSION Z(KZ,1)
C
  SUBROUTINE TO CALCULATE FINITE ELEMENT ...
C
      LUMPED MASS MATRIX:
C
  FOR A PENDING TRIANGLE PLATE ELEMENT WITH UNRESTRAINED BOUNDARIES.
   MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
   THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLANE
   WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE
  X AXIS, AND JOINT 3 IS IN THE POSITIVE Y DIRECTION.
   LOCAL COORDINATE ORDER IS
C
      (DZ,TX,TY) JOINT 1, THEN JCINT 2, 3.
   WHERE DZ IS TRANSLATION AND TX, TY ARE ROTATIONS.
C
   DEVELOPED BY WA BENFIELD. FEBRUARY 1973.
C
  LAST REVISION BY RL WOHLEN. SEPTEMBER 1973.
C
C
C
      SUBRCUTINE ARGUMENTS
C
  X 2
          = INPUT LOCAL X COORDINATE LOCATION OF JOINT 2.
          = INPUT LOCAL Y COORDINATE LOCATION OF JOINT 3.
C
  ·Y3
C
          = INPUT PLATE THICKNESS.
  TH
C
  RO
          = INPUT MASS DENSITY.
          = CUTPUT MASS MATRIX. SIZE(9,9).
CZ
C
 ΚZ
          = INPUT ROW DIMENSION OF 200 IN CALLING PROGRAM. MIN=9. 100
C
      AREA = C.5*X2*Y3
      CM = (RC*TH*AREA)/3.0
      DC. 10 I=1.9
      DC 10 J=1,9
   10\ 2(1,J) = 0.0
      DO 20 I=1,4
   20 \ Z(I,I) = CM
      RETURN :
     END
```

```
SURROUTINE M2E2 (X2, X3, Y3, TH, FHC, Z, T, P, K2, KT, KR)
      DIMENSION 2(KZ,1),T(KT,1),R(KR,1)
      DIMENSION IVEC(1G), COEF(9)
   SUBROUTINE TO CALCULATE FINITE ELEMENT ...
C
C
      CONSISTENT MASS MATRIX,
   FOR A FENDING TRIANGLE PLATE FLEMENT WITH UNRESTRAINED BOUNDARIES.
C
   CUBIC DISPLACEMENT (LINEAR CURVATURE) FIELD IS USED.
   THIS IS NOT THE SU CALLED STRICKLAND ELEMENT.
   MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
   THE LOCAL COORDINATE SYSTEM ASSUMES THE PLATE TO LIE IN AN X-Y PLANE
   WITH JOINT I AT THE X-Y ORIGIN, JOINT 2 LIES ALONG THE POSITIVE:
   X AXIS. AND JOINT 3 IS IN THE POSITIVE Y DIRECTION. . . 5
C
C
   LOCAL COOFDINATE CEDER 15
C
      (DZ,TX,TY) JOINT 1, THEN JOINT 2, 3.
   WHERE DZ IS TRANSLATION AND TX.TY ARE ROTATIONS.
C.
   CALLS FORMA SUPPOUTINES BYABA.
€.
   DEVELOPED BY CAFL PODLEY MARCH 1973.
C
   LAST REVISION BY WA BENFIELD. SEPTEMBER 1973.
      SUBROUTINE ARGUMENTS
C
C
   X2
          = IMPUT LCCAL X COORDINATE LOCATION OF JOINT 2.
                   LOCAL X COOFDINATE LOCATION OF JOINT 3.
   X3
          = INPUT
C
                   LCCAL Y COCPDINATE LOCATION OF JOINT 3.
   Y3
C
          = INPUT
                   PLATE THICKNESS.
          = INPUT
C
   TH
          = INPUT MASS DENSITY.
C
   RHC
          = CUTPUT MASS MATRIX. SIZE(9,9).
C
  Z
C
          = INPUT MATPIX WORK SPACE. SIZE(10,10).
  T
          = IMPUT MATRIX WORK SPACE. SIZE(10,10).
C
  R
C
   ΚZ
          = INPUT FLW DIMENSION OF Z IN CALLING PROGRAM. MIN=9.
          = INPUT RUW DIMENSION OF T IN CALLING PROGRAM. MIN=10.
C
   KT
          = INPUT ROW DIMENSION OF R IN CALLING PROGRAM. MIN=10.
C
   KR
C
      SEI = X3/XS
      SE2 = SE1*SE1
      SE3 = SE2*SE3
      SE4 = SE3#SE1
      SE5 = SE4*SE1
      SF6 = SE5 #SE1
      SEC1 = (1. + 511)/3.
      SEC2 = SEC1**2
      SEC3 = SEC1**3
C
      OC 10 I=1,10
      DC 10 J=1,10
   10 T(I,J) = 0.
C
      T(1,1) = 1.
      T(2.3) = 1.
      T(3,2) = 3.
      T(4,1) = 1.
      T(4,2) = 1.
      T(4,4) = 3.
      T(4,7) = 1.
```

T(5,3) = 1.

```
T(5,5) = 1.
     T(5,8) = 1.
     T(6,2) = 1.
     T(6,4) = 2.
     T(6,7) = 3.
    T(7,1) = 1.
     T(7,2) = SE1
     T(7,3) = 1.
     T(7,4) = SE2
     T(7,5) = SE1
     T(7,6) = 1.
     T(7,7) = SE3
     T(7,8) = SE2
     T(7,9) = SE1
     T(7,10) = 1.
     T(8,3) = 1.
     T(8,5) = SE1
     T(8,6) = 2.
     T(8,8) = SE2
     T(8,9) = 2.*SE1
     T(8,10) = 3.
     T(9,2) = 1.
     T(9,4) = 2.*SE1
     T(9,5) = 1.
    2T(9,7) = 3.*5E2
     T(9,8) = 2.*SE1
     T(9,9) = 1.
     T(10,1) = 1.
     T(10,2) = SEC1
      T(10,3) = 1./3.
      T(10,4) = SFC2
     T(10,5) = SEC1/3
      T(10,6) = 3./9.
    \times T(10,7) = SEC3
      T(10,8) = SEC2/3.
      T(10.9) = SEC1/9.
      T(10,10) = 1./27.
C
      DO 5 1=1,10
     DO 7 J=1,10
    7 R(I,J) = 0.
    5 R(I,I) = 1.
C
      DC 100 L=1,16
      JRIG = 1
      A1 = ABS(Y(L,1))
      DO 15 J=2,10
      A2 = ASS(T(L,J))
      IF (A2 .LT. A1) GO TO 15
      A1 = A2
      JRIG = J
   15 CONTINUE
      IVEC(L) = JEIG
      ALJEIG = T(L, JEIG)
      DC 17 J=1,10
```

```
T(L,J) = T(L,J)/ALJPIG
    17 R(L,J) = F(L,J)/ALJB1G
       DC 25 I=1,10
       AIJFIG = T(I,JEIG)
       IF (I .EQ. L) GC TC 25
       00 30 J=1.10
       T(I,J) = T(I,J) - AIJBIG*T(L,J)
    30 R(I,J) = R(I,J) - AIJBIG*R(L,J) -
    25 CONTINUE
   100 CENTINUE
. ..C
       DO 40 I=1,10
       IF = IVEC(I)
       DC 40 J=1,10
    40 T(IR,J) = R(I,J)
       DC 50 I=1,10
       DO 50 J=1,10
    50 R(I,J) = T(I,J)
       DO 20 I=1,10
       R(1,2) = Y3*P(1,2)^{\circ}
       R(I,3) = -X2*R(I,3)
       R(I,5) = Y3*R(I,5)
       P(I,6) = -X2*P(I,6)

R(I,8) = Y3*P(I,8)
    2G R(1,9) = -X2 + R(1,9)
 C
       CCEF(1) = 1./3.
       CCEF(2) = Y3/18.
       COEF(3) = -(X2+X3)/18.
       COEF(4) = 1./3.
       COFF(5) = Y3/18.
       CDEF(6) = (2.*X2 - X3)/18.
       CDEF(7) = 1./3.
       CCEF(8) = -Y3/9.
       COEF(9) = (2.*X3 - X2)/18.
       DO 80 I=1,10
       DO 80 J=1,9
    80 R(I,J) = R(I,J) + R(I,IU) * COEF(J)
 C
       DO 55 I=1,10
       DC 55 J=1,16
    55 T(1,J) = 0.
 C
       X2Y3 = X2*Y3*TH*RHO
       FOU = X2Y3/2.
       F10 = X2Y3*(1. + SE1)/6.
       F01 = X2Y3/6.
       F20 = X2Y2*(1. + SE1 + SE2)/12.
       F11 = X2Y3*(1. + 2.*SE1)/24.
       FG2 = X2Y3/12.
       F30 = X2Y3*(1. + 561 + 562 + 563)/20.
      \times F21 = X2Y3*(1. + 2.*SF1 + 3.*SE2)/60.
       F12 = X2Y3*(1. + 3.*SE1)/60.
       F03 = X2Y3/20.
```

```
F40 = X2Y3*(1. + SE1 + SE2 + SE3 + SE4)/30.
F31 = X2Y3*(1. + 2.*SE1 + 3.*SE2 + 4.*SE3]/120.
F22 = X2Y3*(1. + 3.*SE1 + 6.*SE2)/180.
F13 = X2Y3*(1. + 4.*SE1)/120.
F04 = X2Y3/30.
F50 = X2Y3*11. + SE1 + SE2 + SE3 + SE4 + SE5)/42.
F41 = X2Y3*(1. + 2.*SE1 + 3.*SE2 + 4.*SE3 + 5.*SE4)/210.
F32 = X2Y3*(1. + 3.*SE1 + 6.*SE2 + 10.*SE31/420.
F23 = X2Y3*(1. + 4.*5E1 + 10.*SE2)/420.
F14 = X2Y2*(1. + 5.*SE1)/210.
F05 = X2Y3/42.
F60 = X2Y3*(1. + SE1 + SE2 + SE3 + SE4 + SE5 + SE6)/56.
F51 = X2Y3*(1.+2.*SE)+3.*SE2+4.*SE3+5.*SE4+6.*SE5)/336.
F42 = X2Y3 + (1.+3.+SE1+6.+SE2+10.+SE3+15.+SE4)/840.
F33 = X2Y3*(1.+4.*SE1+10.*SE2+20.*SE3)/1120.
F24 = X2Y3*(1.+5.*SE1+15.*SE2)/840.
F15 = X2Y3*(1.+6.*SE1)/336.
=F06 = X2Y3/56.
T(1,1) = F00
T(1,2) = F10
^{\circ}T(1,3) = F01
T(1,4) = F2C
T(1.5) = F11
T(1,6) = F02
T(1,7) = F30
T(1,8) = F21
T(1,9) = F12
T(1,10) = F03
T(2,2) = F20
T(2,3) = F11
T(2,4) = F30
T(2,5) = F21
T(2,\epsilon) = F12
T(2,7) = F40
T(2,8) = F31
T(2,9) = F22
T(2,10) = F13
T(3,3) = F02
T(3,4) = F21
T(3,5) = F12
T(3,6) = F03
T(3,7) = F31
T(3, \epsilon) = F22
T(3,9) = F13
T(3,10) = F04
T(4,4) = F40
T(4,5) = F31
T(4,6) = F22
T(4,7) = F50
T(4,8) = F41
T(4,9) = 732
T(4,10) = F23
```

C o

T(5,5) = F22T(5,6) = F13

```
T(5,7) = F41
      T(5,8) = F32
       T(5,9) = F23
       T(5,10) = F14
       T(6,6) = F64
       T(6,7) = F32
       T(6,8) = F23
       T(6,9) = F14
      T(6,10) = F05
      T(7,7) = F60
      T(7,8) = F51
      T(7,9) = F42
       T(7,10) = F33
     T(8,8) = F42

T(8,9) = F33
       T(8,10) = F24
      T(9,9) = F24

T(9,10) = F15

T(10,10) = F06
C
      DC 60 I=1,10 S
       DC 60 J=I,10
    60 \cdot T(J,I) = T(I,J)
    - CALL BTARA (T.R. 10,9,KT.KR)
      DO 85 I=1,9
                      DO 85 J=1,9
    85 Z(I,J) = T(I,J)
, C
       RETURN
       END
```

```
SUBROUTINE MBC1 (X3, Y3, TH, R0, 2, K2)
      DIMENSION Z(KZ,1)
  SUBROUTINE TO CALCULATE FINITE ELEMENT ...
      LUMPED MASS MATRIX
   FOR A RECTANGULAR SHEAR PANEL ELEMENT WITH UNRESTRAINED BOUNDARIES.
C
   MASS MATRIX IS IN LOCAL COORDINATE SYSTEM.
   THE LOCAL COORDINATE SYSTEM ASSUMES THE PANEL TO LIE IN AN X-Y PLANE
   WITH JOINT 1 AT THE X-Y ORIGIN, JOINT 2 LIFS ALONG THE POSITIVE
   X AXIS, JOINT 3 IS IN THE POSITIVE X,Y DIRECTION, AND JOINT 4 LIES
   ALONG THE PUSITIVE Y AXIS.
   LOCAL COORDINATE GROER IS
      DX1, DX2, DX3, DX4, DY1, DY2, DY3, DY4
C
   WHERE DX.DY ARE TRANSLATIONS.
C
   DEVELOPED BY RL WOHLEN. APRIL 1974.
C
      SURROUTINE ARGUMENTS
          = INPU. LOCAL X COOPDINATE LOCATION OF JOINT 3.
C
   X3
C
   Y3
          = INPUT
                   LOCAL Y COURDINATE LOCATION OF JOINT 3.
C
          = IMPUT
                   PANEL THICKNESS.
   TH
C
          = INPUT MASS DENSITY.
   RO
          = CUTPUT MASS MATRIX. SIZE(8,8).
C
   7
C
   ΚZ
          = INPUT ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=8.
C
      CM = RCHTHHX34Y3/4.0
      DO 10 J=1.8
      DC 10 I=1.8
   10 \ Z(I,J) = 6.6
      DC 20 I=1.8
   20 \ Z(I,I) = CM
C
      RETURN -
      EN.J
```

```
SUBROUTINE MASIA (CJ,EJ,A1,A2,RU,NAMEM,Z,KCJ,KEJ,KZ)
      DIMENSION CJ(KCJ,1), EJ(KEJ,1), 2(A2,1)
      DIMENSION E1(3,3), E2(3,3), W(2,2)
C
   SUBROUTINE TO CALCULATE FINITE ELEMENT ...
C
C
      MASS MATRIX
C
   FOR AN AXIAL ROD FLEMENT WITH UNRESTRAINED SOUNDARIES.
   ROD MAY BE LINEARLY TAPERED OR UNIFORM.
   MASS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C
   GLUBAL COORDINATE CROER IS
C
      (U,V,W) JOINT 1, THEN JOINT 2.
C
   WHERE U.V.W ARE TRANSLATIONS.
C
   EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
   CALLS FORMA SUBROUTINES EULER, MIAI, MIA2, ZZBOMB.
C
   DEVELOPED BY RL WOHLEN. SEPTEMBER 1972.
C
   LAST REVISION BY WA BENFIELD. MARCH 1976.
C
C
      SUBROUTINE ARGUMENTS
C
   CJ
                   MATRIX OF GLOBAL X,Y,Z COORDINATES AT ROD JOINTS.
          = INPUT
C
                   ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
                   CULS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).
C
C
                   MATRIX OF EULER ANGLES (DEGREES) AT ROD JOINTS.
   EJ
          = INPUT
                   POWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C
C
                   COLS 1,2 CURRESPOND TO JOINTS 1,2. SIZE(3,2).
                  CROSS-SECTION AREA AT ROD END 1.
C
          = INPUT
   Al
C
                  CPOSS-SECTION AREA AT POD END 2.
   A2
          = INPUT
C
                   MASS DENSITY.
          = INPUT
   RO
                   TYPE OF MASS MATRIX WANTED.
C
   NAMEM = INPUT
C
                   = M1, LUMPED.
C
                   = M2, CONSISTENT.
C
          = DUTPUT MASS MATRIX. SIZE(6,6).
                   POW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
€
  KCJ
          = INPUT
C
   KEJ
          = INPUT
                   ROW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
C
   ΚZ
          = INPUT
                  ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=6.
C
Ċ
      MERROR EXPLANATION
C
   1 = DIMENSION SIZE EXCEEDED (K2).
C
   2 = NAMEM IMPROPERLY DEFINED.
                                                                  NERROR=1
      IF (KZ .LT. 6) GO TO 999
      DC 5 J=1,6
      DO 5 I=1.6
    52(I.J) = 0.0
      RL = SQRT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
                                      + (CJ(3,2)-CJ(3,1))**2)
                              ) GC TC 110
      IF (NAMEM .EQ. 6HM)
      IF (NAMEM .EQ. 6HM2
                             ) 60 TO 120
                                                                  NERROR=2
      GO TO 999
C
  LUMPED.
  110 CALL MIAI
                  (41,A2,RL,RC,W,2)
      DC 112 I=1.3
  112 Z(I,I) = W(I,I)
```

```
DO 114 I=4,6

114 Z(I,I) = W(2,2)
RETURN

C
C CONSISTENT.

120 CALL M1A2 (A1,A2,RL,R0,W,2)
DO 122 Y=1,3

122 Z(I,I) = W(1,1)
CALL EULER (EJ(1,1),E1,3)
CALL EULER (EJ(1,2),E2,3)
CALL ATXBB (E1,E2, 3,3,3, 3,3)
DO 124 I=1,3
DO 124 J=4,6
Z(I,J) = W(1,2)*E2(I,J-3)

124 Z(J,I) = Z(I,J)
DO 126 I=4,6
126 Z(I,I) = W(2,2)
RETURN

C
999 CALL ZZBUMB (6HMASIA ,NERROR)
END
```

```
SUPROUTINE MASIB (CJ,EJ-A1,A2,FI1,PI2,RO,NAMEM,Z,W,KCJ,KEJ,KZ,KW)
      DIMENSION CJ(KCJ, 11, EJ(KEJ, 1), Z(KZ, 1), W(KW, 1)
   SUBROUTINE TO CALCULATE FINITE ELEMENT...
C
      MASS MATRIX
   FUR A COMBINED AXIAL-TORSION-BENDING BAR ELEMENT WITH UNRESTRAINED
C
   BOUNDARIES.
   BAR MAY BE LINEARLY TAPERED OR UNIFORM.
   MASS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
   GLOBAL COORDINATE ORDER 15
      (U,V,W,P,C,R) JOINT 1, THEN JOINT 2
   WHERE U, V, W ARE TRANSLATIONS AND P,Q,R ARE ROTATIONS.
C
   EULER ANGLE CONVENTION IS GLORAL X,Y,Z PERMUTATION.
   CALLS FORMA SUBROUTINES BTABA, DCOSIB, M1A1, M1A2, M1B1, M1B2, M1C1, M1C2,
                            ZZEOME.
C
   DEVELOPED BY RL WOHLEN. FEBRUARY 1973.
C
   LAST REVISION BY WA BENFIELD. MARCH 1976.
C
C
      SUBROUTINE ARGUMENTS
C.
   CJ
          = INPUT
                   MATRIX OF GLOBAL X,Y,Z COORDINATES AT BAR JOINTS.
C
                   ROWS 1,2,3 CORRESPOND TO ",Y,Z COORDINATES.
C
                    COLS 1,2 CORRESPOND TO JUINTS 1,2. COL 3 CORRESPONDS
                    TO REFERENCE POINT TO DEFINE LOCAL XY PLANE. SIZE(3,3).
C
C
          = INPUT
   EJ
                   MATRIX OF EULER ANGLES (DEGREES) AT BAR J. INTS.
\mathbf{c}
                   ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C
                   COLS 1,2 CORPESPOND TO JOINTS 1,2. SIZE(3,2).
C
  A1
          = INPUT
                   CROSS-SECTION AREA AT BAR END 1.
  A2
          = INPUT
                   CROSS-SECTION AREA AT BAR END 2.
  PII
          = INPUT
                   CROSS-SECTION POLAR AREA MOMENT OF INERTIA AT END 1.
  PI2
                   CROSS-SECTION POLAR AREA MOMENT OF INERTIA AT END 2.
C
          = INPUT
C
  RO
          = INPUT
                   MASS DENSITY.
C
   NAMEM = INPUT
                   TYPE OF MASS MATRIX WANTED.
C
                    = M1, LUMPED.
C
                    = M2, CONSISTENT.
C
  Z
          = CUTPUT MASS MATRIX. SIZE(12,12).
C
   W
                   WORK SPACE MATRIX. SIZE(12,12).
          = INPUT
                   PCW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
   KCJ
          = INPUT
                   ROW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
   KEJ
          = IMPUT
                    ROW DIMENSION OF Z IN CALLING PROGRAM. MIN=12.
   ΚZ
          = INPUT
                   ROW DIMENSION OF W IN CALLING PROGRAM. MIN=12.
C
   KW
          = JNPUT
C
      NERROR EXPLANATION
   1 = DIMENSION SIZE EXCEEDED KZ, KW).
C
   2 = NAMEM IMPROPERLY DEFINED.
C
                                                               NERROR=I
      IF (KZ .LT. 12 .0P. KW .LT. 12) 60 TO 999
      DC 5 J=1,12
      DO 5 I=1,12
    5 Z(I,J) = 0.0
      RL = SORT \cdot (CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
                                      + (CJ(3,2)-CJ(3,1))**2)
      IF (MAMEM .FL . SHM1
                              1 GO TO 110
```

) 10 TC 120

IF (NAMEM .EC. 6HM2

NERROR #2

```
GC TC 905
C
  AXIAL=MIAI (LUMPED), TORSION=MICI (LUMPED), BENDING=MIBI (LUMPED).
                  (A1,A2,PL,KC,Z,KZ)
  110 CALL MIAL
                  (PII:PI2, RL, FO, Z(3,3), KZ)
      CALL MICE
      CALL MIST
                  (A1,A2,RL,RC,Z(5,5),KZ)
      CALL MIBI
                  (A1,A2,RL,RO,Z(9,9),KZ)
      GD TD 300
C
  AXIAL=M1A2 (LINEAR DISP), TORSION=M1C2 (LINEAR DISP),
  BENDING=M1F2 (CURIC DISP).
  120 CALL MTA2
                  (#1,A2,RL,RC,Z,KZ)
      CALL MIC2
                  (PX1,PI2,RL,RC,Z(3,3),YZ)
      CALL MIF2
                  (A1,A2,RL,R0,Z(5,5),KZ)
      DO 125 J=7.8
DO 125 I=5.6
      Z(I,J) = -Z(I,J)
  125 2(J,I) = -Z(J,I)
      CALL MIE2
                 (Al,A2,FL,PO,Z(9,9),KZ)
C.
  300 CALL DCC(S1F (CJ,EJ,W,KCJ,KEJ,KW)
      CALL FTARA (2,W, 12,12, KZ,KW)
      RETURN
C
  999 CALL ZZEOME (6HMASIE ,NERROP)
      FNE.
```

(CJ,EJ,TMAS,RO,NAMEM,Z,WI,W2,KCJ,KEJ,KZ,KW1,KW2)

```
DIMENSION CJ(KCJ,1), EJ(KEJ,1), Z(KZ,1), W1(KW1,1), W2(KW2,1)
       DIMENSION IVEC(18)
       DATA IVEC/1,2,6,7,8,12,13,14,18,
                                           3,4,5,9,10,11,15,16,17/
    SUBROUTINE TO CALCULATE FINITE ELEMENT ...
C
C
       MASS MATRIX
C
    FOR A COMEINED MEMBRANE-BENDING TRIANGLE PLATE ELEMENT WITH
   UNRESTRAINED BOUNDARIES.
C
    MASS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C.
    GLOBAL COOPDINATE OFTER IS
C
       (U, V, W, P, C, R) JCINT 1, THEN JCINT 2, 3.
 C
 C
    WHERE U, V, W ARE TRANSLATIONS AND P,Q,P ARE ROTATIONS.
    EULER ANGLE CONVENTION IS GLOBAL X,Y,Z ZERMUTATION.
 C
    CALLS FORMA SUBROUTINES STABA, DCOS2, M2A1, M2A2, M2B1, M2B2, ZZBOMB.
 C
    DEVELOPED BY WA FENHIELD, BL WOHLEN. FEBRUARY 1973.
 C
. .
    LAST REVISION BY WA BENFIELD. MARCH 1976.
C
 C
       SUBROUTINE ARGUMENTS
                    MATRIX OF GLOBAL X,Y,Z COORDINATES AT TRIANGLE JOINTS.
 C
    CJ
          = INPUT
                     ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
 C
                     CCLS 1,2,3 CCRRESPOND TO JOINTS 1,2,3. SIZE(3,3).
 €
 C
    EJ
           = INPUT
                    MATRIX OF EULER ANGLES (DEGREES) AT TRIANGLE JOINTS.
                     RCWS 1,2,3 CCRRESPOND TO GLOBAL X,Y,Z PERMUTATION.
 C
                     CCLS 1,2,3 CORRESPOND TO JOINTS 1,2,3. SIZE(3,3).
 C
    TMAS
                     EFFECTIVE MASS THICKNESS.
 C
           = INPUT
                    MASS DENSITY.
           = INPUT
 C
    RC
                     TYPE OF MASS MATRIX WANTED.
 C
    NAMEM
           = INPUT
                     = M1, LUMPED.
 C
 C
                     = M2, CONSISTENT.
 C
    Z
           = CUTPUT MASS MATRIX. SIZE(18,18).
    Wl
           = INPUT
                    WORK SPACE MATRIY. SIZE(18,18).
                    WORK SPACE MATRIX. SIZE(10,10).
    W2
           = INPUT
                    ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
 C
    KCJ
           = INPUT
                    FOW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
 C
    KEJ
           = INPUT
 C
    ΚZ
           = INPUT
                    FOW DIMERSION OF Z IN CALLING PROGRAM. MIN=18.
 C
    KW1
           = INPUT
                    ROW DIMENSION OF WI IN CALLING PROGRAM. MIN=18.
 C
    KW2
           = INPUT
                    FOW DIMENSION OF WZ IN CALLING PROGRAM. MIN=10.
 C
       NERFOR EXPLANATION
 C
    1 = DIMENSION SIZE EXCEEDED (KZ, KW* - KW2).
 C
    2 = NAMEM IMPROPERLY DEFINED.
 C
                                                                    NEPROP=1
       IF (KZ .LT. 18 .CR. KW1 .LT. 16 .OR. KW2 .LT. 10) GO TO 999
       DC 5 J=1,18
       DC 5 J=1, *P
     5 Z(I_{\nu}J) = C \cdot C
       SL12 = SOFT((CJ(1,2)-CJ(1,1)) \neq 2 + (CJ(2,2)-CJ(2,1)) \neq 2
                                          + (CJ(3,2)-CJ(3,1))**2)
       SL23 = SOPT((CJ(1,2)-CJ(1,2))**2.+ (CJ(2,3)-CJ(2,2))**2
                                          + (CJ(3,3)-CJ(3,2))**2)
       SL13 = SG^{T}((CJ(1,3)-CJ(1,1))**2 + (CJ(2,3)-CJ(2,1))**2
                                          + (CJ(3,3)-CJ(3,1))**2)
            = (St13**2+St12**2-St23**2)/(2.0*St12)
       X3
```

SUPROUTINE MASS

```
Y3 = SQRT(SL13**2-X3**2)
      IF (NAMEM .EQ. 6HM1 ) GC TC 110
                               ) GC TO 120
      IF (NAMEM .EC. 6HM2
                                                                        NERROR=2
      60 TO 999
C
  MEMERANE = M2A1 (LUMPED), SENDING = M2F1 (LUMPED).
  110 CALL M2A1 (SL22,Y3,TMAS,RC,W1,KW1)
CALL M251 (SL12,Y3,TMAS,RC,W1(10,10),KW1)
      DC 115 IW=1,18
      IZ = IVFC(IW)
  115 \ 2(17,12) = W1(1W,1W)
      RETURN
  MEMBRANE = M2A2 (CONSISTENT), BENDING = M2E2 (CONSISTENT).
  120 CALL M2A2 (SL12, X3, Y3, TMAS, RD, Z, W1, W2, KZ, KW1, KW2)
      CALL M2F2 (SL12,X3,Y3,TMAS,PO,Z(10,10),W1,W2,KZ,KW1,KW2)
CALL DCDS2 (CJ,EJ,W1,KCJ,KEJ,KW1)
      CALL BTABA (Z.WI.18, 18, KZ.KWI)
      PETURN
C
  999 CALL ZZEOMB (SHMAS2 ,NERFOR)
      END
```

NERROR=2

```
SUPROUTINE MASS (CJ,EJ,TMAS,RC,NAMEM,Z,WI, '2,KCJ,KEJ,KZ,KWI,KW2)
DIMENSION CJ(KCJ,I),EJ(KEJ,I),Z(KZ,I),WI(KWI,I),WZ(KW2,I)
      DIMENSION CW(3,3), EW(3,3), IVI(18), IV2(18), IV3(18), IV4(18),
                 W3(10,10)
      DATA IVI/ 1, 2, 3, 4, 5, 6, 7, 8, 9,10,11,12,13,14,15,16,17,18/,
           172/ 1, 2, 3, 4, 5, 6, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24/,
     *
           143/ 1, 2, 3, 4, 5, 6, 7, 8, 9,10,11,12,19,20,21,22,23,24/,
           14/ 7, 8, 9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24/
C.
   SUBROUTINE TO CALCULATE FIGHTE FLEMENT ...
C
      MASS MATRIX
C
   FOR A COMBINED MEMBRANE-BENDING QUADRILATERAL PLATE ELEMENT WITH
C
   UNRESTRAINED ECUNDARIES.
C
   MASS MATRIX IS IN GLOBAL COOPDINATE DIRECTIONS.
C
   GLOBAL COORDINATE ORDER IS
      (U,V,w,P,Q,R) JOINT 1, THEN JOINT 2, 3, 4.
   WHERE U, V, W ARE TRANSLATIONS AND P, O, R ARE POTATIONS.
   EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
   CALLS FORMA SCEROUTINES MASS, REVADD, ZZEOME.
   DEVELOPED BY WA BENFIELD, RL WOHLEN. FEBRUARY 1973.
   LAST REVISION BY WA BENFIELD. MARCH 1976.
C
C
C
      SUBFOUTINE ARGUMENTS
C
   CJ
          = INPUT
                   MATRIX OF GLOBAL X,Y,Z COORDINATES AT QUAD JOINTS.
                    POWS 1,2,3 CORRESPOND TO X,Y,7 COORDINATES.
C
                    CCLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C
                    MATRIX OF FULER ANGLES (DEGREES) AT CUAD JOINTS.
C
          = INPUT
   EJ 
                    RCWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C
                    COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C
                    EFFECTIVE MASS THICKNESS.
C
   TMAS
          = INPUT
C
   RC
          = INPUT
                    MASS DENSITY.
                    TYPE OF MASS MATRIX WANTED.
   NAMEM
          = INPUT
C
                    = M1, LUMPED. 4 TRIANGLES, OVERLAP AVERAGE.
                    = M2, CONSISTENT. 4 TRIANGLES, OVERLAP AVERAGE.
C
          = CUTPUT MASS MATRIX. SIZE(24,24).
C
   2
          = IVPUT
                    WORK SPACE MATRIX. SIZE(18,18).
C
   Wi
                    WORK SPACE MATRIX. SIZE(18,18).
C
   w2
          = INPUT
          = INPUT
                   ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C
   KCJ
          = INPUT
                    FOW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
C
   KEJ
          = IMPUT
                    FOW DIMENSION DE Z IN CALLING PROGRAM. MIN=24.
C
   ΚZ
          = INPUT
                   HOW DIMENSION OF WI IN CALLING PROGRAM. MIN=18.
C
   KW1
          = INPUT FOW DIMENSION OF W2 IN CALLING PROGRAM. MIN=18.
C
   KW2
      NERRCH EX CANATION
C
C
   1 = DIMENSION SIZE EXCEEDED (K2, KW1, KW2).
C
   2 = NAMEM IMPPOPERLY DEFINED.
                                                                   NERROR=1
      IF (KZ .LT. 24 .CR. KN] .LT. 18 .CR. KW2 .LT. 18) GO TO 999
      DO 5 J=1,24
      DC 5 I=1,24
    52(1,J) = 0.0
      IF (NAMEM .EC. 6HM)
                             ) or he 110
                              ) GC TC 110
      IF (NAMEM .EQ. 6HM2
```

```
GC TC 999
C
  110 DO 112 I=1,3
       CW(I,1) = CJ(I,1)
       EW(I,I) = EJ(I,I)
       CW(I,2) = CJ(I,2)
       EW(I,2) = EJ(I,2)
       CW(I,3) = CJ(I,3)
  112 EW(I,3) = EJ(I.3)
                      (CW, EW, TMAS, RO, NAMEM, W1, W2, W3, 3, 3, KW1, KW2, 10)
       CALL MAS2
       CALL REVADD (.5, W1, IV1, IV1, Z, .18, 18, 24, 24, KW1, KZ)
       DC 113 1=1,3
       CM(I,1) = CJ(I,1)
       \mathsf{EW}(\mathsf{I},\mathsf{1}) = \mathsf{EJ}(\mathsf{I},\mathsf{1})
       CW(1,2) = CJ(1,3)
       EW(1,2) = FJ(1,3)
       CW(I,3) = CJ(I,4)
  113 \text{ EW}(I,3) = \text{FJ}(I,4)
       CALL MASS
                      (CH, EN, TMAS, RC, NAMEM, WI, H2, W3, 3, 3, KWI, KW2, 10)
       CALL REVADO (.5, W1, IV2, IV2, Z, 18, 18, 24, 24, KW1, KZ)
       DO 114 I=1.3
       CW(I,1) = CJ(I,1)
       \mathsf{EW}(\mathsf{I},\mathsf{I}) = \mathsf{EJ}(\mathsf{I},\mathsf{I})
       CW(I,2) = CJ(I,2)
       EW(1,2) = EJ(1,2)
       CW(1,3) = CJ(1,4)
  114 EW(I,3) = EJ(I,4)
                     (CW, EW, TMAS, RC, NA"EM, W1, W2, W3, 3, 3, KW1, KW2, 10)
       CALL MAS2
       CALL REVADD (.5, W1, IV3, IV3, Z, 18, 18, 24, 24, KW1, KZ)
       DO 115 I=1.3
       C'(I,1) = CJ(I,2)
       EW(I,1) = EJ(I,2)
       CW(I,2) = CJ(I,3)
       EW(I,2) = FJ(I,2)
       CW(1,3) = CJ(1,4)
  115 EW(I,3) = EJ(I,4)
       CALL MASS
                     (CW, FW, TM AS, RP, NAMEM, W1, W2, W3, 3, 3, KW1, KW2, 10)
       CALL REVADD (.5, W1, IV4, IV4, 2, 18, 18, 24, 24, KW1, KZ)
       RETURN
  999 CALL ZZBOMB (5HMAS3 ,NERROR)
       END
```

```
SUPPOUTINE MASSA (CJ,EJ,TMAS,RO,NAMEM,Z,WI,W2,KCJ,KEJ,KZ,KWI,KW2)
      DIMENSION CJ(KCJ,1), 5J(KEJ,1), Z(KZ,1), W1(KW1,1), W2(KW2,1)
C
  SUPPOUTINE TO CALCULATE FINITE ELEMENT ...
C
      MASS MATRIX
C
 FOR A RECTANGULAR SHEAR PANEL ELEMENT WITH UNRESTRAINED BOUNDARIES.
C.
   MASS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
   GLOBAL COORDINATE OFFER IS
      (U,V,W) JOINT 1, THEN JOINT 2, 3, 4.
C
   WHERE U.V.W ARE TRANSLATIONS.
   EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C
   CALLS FORMA SUBROUTINES M3C1, ZZEOMB.
C
   DEVELOPED BY RL WOHLEN. APRIL 1974.
C
   LAST PEVISION BY PL WOHLEN. MAY 1976.
C
      SUBROUTINE APQUMENTS
          = INPUT MATRIX OF GLOBAL X,Y,Z CCORDINATES AT PANEL JOINTS.
C
   CJ
                   POPS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C
C
                   CCLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
                   MATRIX OF EULER ANGLES (DEGREES) AT PANEL JOINTS.
C
   EJ
          = INPUT
                   FOWS 1,2,3 CORRESPOND TO GLOBAL X,Y, Z PERMUTATION.
C
                   CCLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C
                   EFFECTIVE MASS. THICKNESS.
C
   TMAS
          = INPUT
          = INPUT
                   MASS DENSITY.
   RO
C
          = INPUT
                  TYPE OF MASS MATRIX WANTED.
   NAMEM
                   = M1, LUMPED.
C
   7
          = CUTPUT MASS MATRIX. SIZE(12.12).
          = INPUT WORK SPACE MATRIX. SIZE(12,12).
C
   WI
C
          = INPUT WERK SPACE MATRIX. SIZE(**,**).
   W2
                   ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C
          = INPUT
   KCJ
          = INPUT ROW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
C
   KEJ
          = INPUT FOW DIMENSION OF Z IN CALLING PROGRAM. MIN=12.
C
   ΚZ
                   ROW DIMENSION OF WI IN CALLING PROGRAM. MIN=12.
          = INPIT
C
   KW1
          = INPUT ROW DIMENSION OF W2 IN CALLING PROGRAM. MIN: *.
C
   KM2
      NEFPOR EXPLANATION
Ü
   1 = DIMENSION SIZE EXCEEDED (KZ.KW1.KW2).
C
   2 = NAMEM IMPROPERLY DEFINED.
C
                                                                 NERROR=1
      IF (KZ .LT. 12 .NF. KW1 .LT. 12 .OR. KW2 .LT. 0) GO TO 999
      SL12 = SQRT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
                                        + (CJ(3,2)-CJ(3,1))**2)
      SL14 = SGRT((UJ(1,4)-CJ(1,1))**2 + (CJ(2,4)-CJ(2,1))**2
                                        + (CJ(3,4)-CJ(3,1))**2}
                              ) GC TC 110
      IF (NAMEM .FC. 6HMI
                                                                 NERROR=2
      66 10 600
C
  LUMPED.
  110 DO 112 J=1,12
      DC 112 1=1,12
  112 Z(i,J) = 0.0
      CALL MSCI (SLIZ, SLIA, TMAS, RO, WI, KWI)
      DC 115 TW=1,4
```

```
IZ = 3*(IW-1)

Z(IZ+1,IZ+1) = W1(IW,IW)

Z(IZ+2,IZ+2) = W1(IW,IW)

115 Z(IZ+3,IZ+3) = W1(IW,IW)

RETURN

C

999 CALL ZZBOMB (6HMAS3A ,NERROR)

END
```

```
SUBROUTINE PRESS (CJ, T, NJN, NCOL, KCJ, KW)
      DIMENSION CJ(KCJ,1),T(KW,1)
      DIMENCION A(8,8), JNM(3,42), VN(3), C(3,9), IV(3), JV(9)
C
C
C ***
       SUBPOUTINE TO CALCULATE FLUID ELEMENT PRESSURE TRANSFORMATION
C
 ***
       MORE DESCRIPTIVE COMMENT CARDS TO BE ADDED AT A LATER DATE.
C ***
                  DEVELOPED BY CAPL BODLEY. OCTOBER 1974.
C
  LAST REVISION BY C S BODLEY. NOVEMBER 1974.
C
      DATA JNM
     *
         1,2,3,
                  2,4,3,
                                   1,4,2,
                                            1,2,3,
                          3,4,1,
                                                    6,5,4,
                                                    3,4,1,
                           4,5,2,
                                   4,2,1,
                  2,5,6,
                                            3,6,4,
         2,6,3,
     *
         3,5,0,
                  3,2,5,
                           4,5,1,
                                   1,5,2,
                                            1,3,6,
                                                    1,6,4,
         1,5,2,
                  5,6,2,
                           5,8,7,
                                   5,7,6,
                                            4,7,8,
                                                    4,3,7,
                                   4,8,5,
                                                    2,7,3,
         1,2,4,
                  2,3,4,
                           1,4,5,
                                            2,6,7,
         1,5,6,
                  1,6,2,
                           5, 8, 6,
                                   6,8,7,
                                            3,7,8,
                                                    3,8,4,
         1,2,3,
                  1,3,4,
                           1,8,5,
                                   1,4,8, 2,6,3,
                                                    6,7,3 /
C
      CALL ZERG
                  (T,NJN,NCOL,KW)
      L0 = 18
      NTF = 24
      IF (NJN .EQ. 8) GO TO 5
      LO = 4
      NTF = 14
      IF (NJN .EQ. 6) GO TO 5
     = L0 = 0
      NTF = 4
    5 CONTINUE
C
      DO 20 N=1.NTF
      LOC = N + LC
      J1 = JNM(1,LEC)
      J2 = JNM(2,L00)
      J3 = JNM(3, ECC)
      VN(1)=(CJ(2,J2)-CJ(2,J1))*(CJ(3,J3)-CJ(3,J1))
     * -(CJ(3,J2)-CJ(3,J1))*(CJ(2,J3)-CJ(2,J1))
      VN(2)=(CJ(3,J2)-CJ(3,J1))*(CJ(1,J3)-CJ(1,J1))
     * -(CJ(1,J2)-CJ(1,J1))*(CJ(3,J3)-CJ(3,J1))
      VN(3) = (CJ(1,J2) - CJ(1,J1)) * (CJ(2,J3) - CJ(2,J1))
     * -(CJ(2,J2)-CJ(2,J1))*(CJ(1,J3)-CJ(1,J1))
      \pm C = SQFT(VN(1) + VN(1) + VN(2) + VN(3) + VN(3) + VN(3)
      DO 25 I=1,3
   25 \text{ VN(I)} = \text{VN(I)/AC}
      AC = AC/4E.
      IF (LOC .LT. 6) AC = 2.*AC
      DO 36 I=1.3
      IV(I) = JNM(I,LOC)
      DC 30 J=1,3
      JI = 3*I - 3 + J
      JL = (IV(I) - 1)*3 + J
   30 \text{ JV(JI)} = \text{JL}
C
      DC 35 L=1,3
      DO 35 I=1.3
```

```
IL = I + 3*(L - 1)
      DO 35 J=1,3
      F = 1.
      IF (L .EQ. J) F = 2.
   35 C(J,IL) = F*VN(I)
      CALL REVADD (AC,C,IV,JV,T,3,9,NJN,NCOL,3,KW)
   20 CONTINUE
C
      DC 40 I=1,NJN
      DC 40 J=I,NJN
      A(I,J) = 0.
      DO 40 K=1,NCOL
   40 \text{ A(I,J)} = \text{A(I,J)} + \text{T(I,K)*T(J,K)}
      CALL INVINP (A,A,NJN,8)
      CALL MULTE (A,T,NJN,NJN,NCOL,8,KW)
C
      RETURN
      END
```

```
CAUD SMITUORS.
                        (XYZ, JDOF, EUL, NUTEL, NJ,
                         NUTMX, NUTKX, NUTBX, NUTLT, NUTST,
                         W, T, S, KX, KJ, KE, KW)
      DIMENSION XYZ(KX,1),JDOF(KJ,1),EUL(KE,1),W(KW,1),T(KW,1),S(KW,1)
      DIMENSION CJ(3,4),EJ(3,4),IV1(24)
      DATA NAMEL/6HQUAD /.NRW,NRLT/24,24/, IBLNK/6H
                                                          /, KCJ/3,
      DATA NIT, NOT/5,6/
   SUBPOUTINE TO CALCULATE (CN OPTION) FINITE ELEMENT ...
C
      MASS MATRICES AND IVECS (ON NUTMX),
      STIFFNESS MATRICES (SAME AS GLOBAL LOAD TRANSFORMATION MATRICES)
ſ
      AND IVECS (ON NUTKX).
      UNIT LOAD EUCKLING MATRICES AND IVECS (ON NUTBX), (NOT YET)
C
      LOCAL LOAD TRANSFORMATION MATRICES AND IVECS (ON NUTLT), (NOT YET)
C
      STRESS TRANSFORMATION MATRICES AND IVECS (ON NUTST), (NOT YET)
   FOR COMPINED MEMBRANE-BENDING QUADRILATERAL PLATE ELEMENTS.
C
   MASS, STIFFNESS, BUCKLING MATRICES ARE IN GLOBAL COORDINATE
C
   DIRECTIONS.
C
   GLOBAL COOPDINATE ORDER IS
C
      (U, V, W, P, Q, P) JOINT 1, THEN JOINT 2, 3, 4.
C
   WHERE U, V, W ARE TRANSLATIONS AND POOR ARE ROTATIONS.
C
   IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
      IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
C
                  OMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINS
C
      IVEC(3)=0
                  ELEMENT DOF 3 TO ZERO MOTION.
  GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT QUAD VERTICES IN
C
   GLOBAL COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C
C
   DIRECTIONS.
   ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C
C.
      (PU, PV, PW, MP, MQ, MF) JOINT 1, THEN JOINT 2,3,4.
   WHERE P IS EDECE AND M IS MOMENT.
•
   LOCAL LOAD TRANSFORMATION MATRICES RELATES LOAD AT QUAD VERTICES IN
C
  LOCAL COURDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COURDINATE
C
   DIRECTIONS.
C
   STRESS TRANSFORMATION MATRICES RELATES STRESS AT QUAD VERTICES IN
C
   LOCAL COOPDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
C
   DIRECTIONS.
   DATA ARRANGEMENT ON NUTMX, NUTKX, NUTBX, NUTLT, NUTST FOR EACH FINITE
C
C
   ELEMENT IS (W=M,K,P,LT,ST)
C
      WRITE (NUTWX) NAMEW, NEL, NR, NC, NAMEL, (IBLNK, I=1,5),
                    ((N(I,J),I=1,NR),J=1,NC),(IVEC(I),I=1,NC)
C.
   CALLS FORMA SUFRCUTINES MASS, PAGEND, STF3, ZZPOMB.
C
   DEVELOPED BY WA PENFIFLD, CS BODLFY, RL WOHLEN. MARCH 1973.
C
   LAST REVISION BY RL WOHLEN. MAY 1976.
C
C
   C
   INPUT DATA PEAD IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = 5, DATA IS
C
C
   READ FROM CAFDS.
      NAMEM, NAMEK, NAMELT, NAMEST, NAMEE
                                                  FORMAT (5(A6,4X)
C
                                                  FORMAT (3(5X,E10))
C
      PO, E, ANU
C
      TMASC. TMEMC. TRENC
                                                  FORMAT (3(5X,E10))
   20 NEL, J1, J2, J3, J4, TMASV, TMEMV, TEENV
                                                  FORMAT (515, E10)
C
      IF (J1 .FQ. O) PETUEN
C
      GC TC 26
C
```

C

```
DEFINITION OF INPUT VARIABLES.
         = TYPE OF MASS MATRIX WANTED.
C
   NAMEM
            = MI, DIAGONAL LUMPED. DVERLAP AVERAGE OF FOUR TRIANGLES.
C
C
            = M2, CONSISTENT. OVERLAP AVERAGE OF FOUR TRIANGLES.
C
            = 6H
                       OR SHNUMASS, NO MASS MATRIX CALCULATED.
C
         = TYPE OF STIFFNESS MATRIX WANTED.
   NAMER
            = KI, CVERLAP AVERAGE OF FOUR TRIANGLES.
C
                       OR 6HNCSTIF, NO STIFFNESS MATRIX CALCULATED.
C
            = 6H
C
   NAMELT = IDENTIFICATION NAME FOR LOAD TRANSFORMATION MATRICES.
C
            = 6H
                       OR SHNCLCAD, NO LOAD TRANSFORMATIONS CALCULATED.
C
   NAMEST = IDENTIFICATION NAME FOR STRESS TRANSFORMATION MATRICES.
C
            = 6h
                       OR 6HNOSTRS, NO STPESS TRANSFORMATIONS CALCULATED.
C
          = TYPE OF BUCKLING MATRIX WANTED.
                       OR SHNOBUCK, NO BUCKLING MATRIX CALCULATED.
C
            = 6H
C
          = MASS DENSITY.
   RC
C
          = YOUNGS MODULUS OF ELASTICITY.
   E
C
   ANU
          = POISSONS PATIO. (E/2G)-1.
C
          = EFFECTIVE MASS
                               THICKNESS, (CONSTANT).
   TMASC
C
   TMASV
         = EFFECTIVE MASS
                               THICKNESS, (VARIABLE).
C
            IF .LF. O., TMASC IS USED.
C
          = EFFECTIVE MEMBRANE THICKNESS, (CONSTANT).
   TMEMC
         = EFFECTIVE MEMERANE THICKNESS; (VARIABLE).
C
   TMEMV
C
            IF .LE. O., TMEMC IS USED.
C
   TBENC
          = EFFECTIVE BENDING
                               THICKNESS, (CONSTANT).
C
         = FFFECTIVE BENDING
                               THICKNESS, (VARIABLE).
   TBENV
            IF .LE. G., TEENC IS USED.
C
          = FINITE ELEMENT NUMBER. FOR REFERENCE ONLY, NOT USED IN
C
   NEL
C
            CALCULATIONS. WRITTEN ON NUTMX. ETC.
C
          = JOINT NUMBER AT QUADRILATERAL VERTEX 1.
   Jl
C
          = JOINT NUMBER AT QUADRILATERAL VERTEX 2.
   J2
          = JOINT NUMBER AT QUADRILATERAL VERTEX 3.
C
   J3
C
          = JOINT NUMBER AT QUADRILATERAL VERTEX 4.
   J4
C
C
   EXPLANATION OF INPUT / COMATS. NUMBER INDICATES CARD COLUMNS USED.
C
      I = INTEGER DATA, RIGHT ADJUSTED.
C
      E = DECIMAL PCINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT, ADJUSTED
C
      X = CARD COLUMNS SKIPPED.
C
   ********************************
C
C
      SUPPOUTINE APGUMENTS (ALL INPUT)
C
          = MATEIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWS CORRESPOND
C
            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C
            X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ,3).
          = MATRIX OF JOI'T GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND
C
   JDOF
            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C
C
            TRANSLATION DOES AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
C
            ROTATION DOFS. SIZE (NJ, 6).
          # MATRIX OF JOINT FULER ANGLES (DEGREES). ROWS CORRESPOND
C
   EUL
            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
C
            GLOUAL X,Y,2 PERMUTATION. SIZE(NJ,3).
          = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
C
   NUTEL
            THIS SUFFECUTINE. IF NUTEL = 5. DATA IS READ FROM CARDS.
C
C
          = NUMBER OF JOINTS OF ROWS IN MATRICES (XYZ), (JDOF), (EUL).
   NJ
          ECGICAL NUMBER OF UTILITY TAPE ON WHICH FLEMENT
C
   NUTMX
            MASS MATRICES AND IVERS ARE CUTPUT.
C
```

```
NUTMX MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
            USES FORTRAN READ, WRITE.
   NUTKX
         = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
            STIFFNESS MATPICES (SAME AS GLOBAL LOADS TRANSFORMATION
C
            MATRICES) AND IVECS ARE OUTPUT.
C
            NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C
C
            USES FORTRAN READ, WRITE.
C
   NUTBX
         = LCGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT UNIT LOAD
            BUCKLING MATRICES AND IVECS ARE OUTPUT.
C
C
            NUTEX MAY BE ZERO IF BUCKLING MATRIX IS NOT FORMED.
C
            USES FORTRAN READ, WRITE.
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOCAL
C
   NUTLT
            LOAD TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C
            NUTLY MAY BE ZERO IF LOAD TRANSFORMATIONS ARE NOT FORMED.
C
C
            USES FORTRAN PEAD, WRITE.
C
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
            STRESS TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C
            NUTST MAY BE ZERO IF STRESS TRANSFORMATIONS ARE NOT FORMED.
C
C
            USES ECETRAN READ, WRITE.
C
          = MATRIX WORK SPACE. MIN SIZE(24,24).
  W
C
          = MATEIX WORK SPACE. MIN SIZE(24,24).
  T
C
          = MATRIX WORK SPACE. MIN SIZE(24,24).
   ~
          = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
C
   ΚX
          = ROW DIMENSION OF JOOF IN CALLING PROGRAM.
C
  ΚJ
          = ROW DIMENSION OF EUL IN CALLING PROGRAM.
C
  ΚE
          = ROW DIMENSION OF W, T, AND S IN CALLING PROGRAM. MIN=24.
C
  KW
C
C
      NERROR EXPLANATION
   1 = JOINT NUMBER GREATER THAN NUMBER OF JUINTS.
   2 = MASS MATRIX FORM D, NUTMX .LE. ZERC.
   3 = STIFFNESS MATPIX FORMED, NUTKX .LE. ZERO.
  4 = LT MATRIX FORMED, NUTLT .LE. ZERO.
C
   5 = ST MATPIX FORMED, NUTST .LE. ZERO.
 1001 FORMAT (5 (A6,4X))
 1002 FORMAT (3(fX,F10.0))
 1003 FORMAT (515,3E10.0)
 2001 FORMAT (//25X 40HINPUT DATA FOR COMBINED MEMBRANE-BENDING
                    29H QUADRILATERAL PLATE ELEMENTS)
 2002 FORMAT (//20X 40HINPUT DATA FOR COMPINED MEMERANE-BENDING
                    41H QUADRILATERAL PLATE ELEMENTS (CONTINUED))
 2003 FORMAT (/ 13X7HMASS = 46, 13X7HSTIF = A6, 6X13HLOAD TRANS = A6,
                SXISHSTRESS TRANS = A6, 3XIIHPUCKLING = A6,
     *
              / 15X4FEC = E10.3, 13X3HE = E10.3,
              / 10X9HT(MASS) = E10.3, 12X4HNU = E10.3,
              / 32X13HT (MEMBRANE) = E10.3.
              / 33x12HT(PENDING) = E10.3,
              //12X THELEMENT 5X THUCINT 1 5X THUOINT 2 5X THUOINT 3
                 5x 7hJCINT 4 5x 7hT(MASS) 6x 11hT(MEMERANE)
                 5x 10HT(FENDING)
               /12X SHNUMFER 46% 3(5X 10H(VARIABLE) ) )
 2004 FORMAR (12X 5(15,7X),3((10.0,5X))
 2005 FORMAT (12% - (15,7%) )
  READ AND WRITE FINITE FLEMENT DATA.
```

```
NLINE = 0
      CALL PAGEND
      WRITE (NOT,2001)
      READ (NUTEL, 1001) NAMEM, NAMEK, NAMELT, NAMEST, NAMEB
      READ (NUTEL, 1002) RO, E, ANU
      READ (NUTEL, 1002) TMASC, TMEMC, TBENC
      WRITE (NOT, 2003) N' MEM, NAMEK, NAMELT, NAMEST, NAMEB,
                        RC, E, TMASC, ANU, TMEMC, TBENC
   20 READ (NUTEL, 1003) NFL, J1, J2, J3, J4, TMASV, TMEMV, TBENV
      NO THIK = 1
      IF (TMASV-LE-0. -AND. TMEMV-LE-0. -AND. TBENV-LE-0.) NO FHIK=0
      IF (J1 .LE. G) RETURN
      NLINE = NLIME + 1
      IF (NLINE .LE. 42) 90 TO 30
      CALL PAGEHD
      WRITE (NGT,2002)
      WRITE (NOT, 2003) NAMEM, NAMER, NAMELT, NAMEST, NAMEB,
                        RO,E, TMASC, ANU, TMEMC, TBENC
      NLINE = 0
   30 IF (NO THIK.EQ.I)
     *WRITE (NCT,2004) NEL, J1, J2, . 3, J4, TMASV, TMEMV, TBENV
      IF \NC .THIK.EQ.0) WRITE (NOT, 2005) NEL, J1, J2, J3, J4
                                                                     NERROR=1
      IF (J1.GT.NJ.OR. J2.GT.NJ.OR. J3.GT.NJ.OR. J4.GT.NJ) GU TU 999
C
  SET THICKNESSES.
      TMAS = TMASC
      TMEM = TMEMC
      TEEN = TEENC
      IF (TMASV.GT.O.) TMAS=TMASV
      IF (TMEMV.GT.G.) TMEM=TMEMV
      IF (TRENV.GT.O.) TREN=TEENV
C
€.
  FORM FINITE ELEMENT COORDINATE EDCATIONS, FULER ANGLES, REVADD IVEL.
      DO 42 I=1,3
      CJ(I,1) = XY7(J1,I)
      CJ(1:2) = YYZ(J2,1)
      CJ(I_{+1}) = XYZ(J3_{+}I)
      CJ(I_{*}/i) = XYZ(14*I)
      FJ(1,1) = -CUE
                     [ . I)
                       ,1)
      EJ(T_{1/2}) = 0

≤ , I )
      EJ(1,3) =
   42 EJ(1,4) = JL(J4,1)
      DO 44 1=1.6
      IV1(I)
                = JDCF(JI,I)
      IVI(I+6) = JDUF(J2,I)
      1V1(1+12) = JDCF(J3,I)
  -44 \text{ IV}(I+18) = \text{JDCF}(J4,I)
C
C - FORM MASS MATRIX (W).
      IF AME: FG. 6F
                                .CR. NAMEM .CQ. 6HNOMASS) GO TO 110
           MACC
                   (CJ,EJ,TMAS,FC,NAMEM,W,F,S,KCJ,KCJ,KW,KW,KW)
                                                                     NERROR=2
      IF (MUTMX .LF. C) GC TC 999
      WRITE (NUTMX) NAMEM, NEL, NRW, NEW-NAMEL, (IPENK, I=1, S),
```

```
((W(I,J),I=1,NRW),J=1,NRW),(IV1(I),I=1,NRW)
C
C
   FORM STIFFNESS MATRIX (W), LOCAL LOAD TRANSFORMATION MATRIX (T),
  STRESS TRANSFORMATION MATRIX (S).
  110 IF (NAMEY .EC. 6H
                              .OR. NAMEK .SQ. 6HNOSTIF) GO TO 20
      CALL STF3
                   (CJ, EJ, TMEM, TBEN, E, ANU, NAMEK, NAMEST, W, T, S, NRST,
     *
                    K.C.J., KC.J., KW., KW., KW.)
                                                                    NERROR=3
      IF (NUTKX .LE. 0) GD TO 979
      WRITE (NUTKX) NAMEK, NEL, NRW, NRW, NAMEL, (IELNK, I=1,5),
                     ((W(I,J),I=1,NRW),J=1,NRW),(IVI(I),I=1,NRW)
      IF (NAMELT .EQ. 6H
                                 .UF. NAMELT .EQ. 6HNOLDAD) GO TO 115
                                                                    NERROK=4
      IF (NUTLT .LE. 0) CO TO 999
      WRITE (NUTLE) NAMELT, MEL, WRLT, NRW, NAMEL, (INLNK, I=1.5),
                     ((T(I,3),l=1,NRLT),J=1,NRW),(TV1(I),I=1,NRW)
  115 IF (NAMEST .EQ. 6H
                                 .CR. NAMEST .EC. 6HNOSTRS) GG TO 20
                                                                    NERROP=5
      IF (MUTST .LE. /) GD TD 999
      WRITE (NUTST) NAMEST, NEL, NRST, NRW, NAMEL, (IBLNK, I=1,5),
                     ((S(I,J), I=1, NRST), J=1, NRW), (IV1(I), I=1, NRW)
      GC TC 20
C
  999 CALL ZZEOMP (6HQUAD ,NERROR)
      END
```

```
SUBFORTINE RECTSP (XYZ, JDOF, EUL, NUTFL, NJ,
                         NUTMX, NUTKX, NUTLT, NUTST,
                         W, T, S, KX, KJ, KE, KW)
     EIMENSION XYZ(KX,1),JDDF(KJ,1),EUL(KE,1),W(KW,1),T(KW,1),S(KW,1)
     [37]ENSION CJ(3,4),EJ(3,4),IV1(12)
      MAIA NAMEL/6HRECTSP/, NRW,NRLT/12,8/, IBLNK/6H
                                                          /, KCJ/3/
     TIATA NIT, NOT/5,6/
   SU: . JUTINE TO CALCHEARE (ON OPTION) FINITE ELEMENT ...
C
     THASS MATRICES AND YECS (ON NUTHX).
      SCIFFRESS MATRICES ISAME AS GLOBAL LOAD TRANSFORMATION MATRICES!
      AND IVECS (ON NUTRX),
      LUCAL LOAD TRANSFORMATION MATRICES AND IVECS (ON NUTLT).
     -STRESS TRANSFORMATION MATRICES AND IVECS (ON NUTST),
  FOR RECTANGULAR SHEAP PANEL ELEMENTS.
  MATS, STITEMESS MATRICES ARE IN GLOBAL COORDINATE DIRECTIONS.
C
   GI DEAL COORDINATE ORDER IS
      (U, V, W) JOINT 1, THEN JOINT 2, 3, 4.
   WHERE U, V, W APE TRANSLATIONS.
C
   IVEC GIVES ELEMENT DOF INTO GLOBAL DOF. EXAMPLES...
C
      IV" (6) = 834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
C
                  PMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINS
C
      IV: ((3)=0
                  ELEMENT DOF 3 TO ZERO MOTION.
  GLUEAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT PANEL VERTICES IN
C
  GLOBAL CROPPINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
  DIRECTIONS.
   ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
      (PU, PV, PW) JOINT 1, THEN JOINT 2, 3, 4.
  WHERE P IS FORCE.
   LOCAL LOAD TRANSFORMATION MATRICES RELATES LOAD AT PANEL VERTICES IN
  LOCAL COOPDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
  DIRECTIONS.
C
  STRESS TPANSFORMATION MATRICES RELATES PANEL SHEAR STRESS (CONSTANT)
C
  IN LOCAL COOPDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COOPDINATE
C
  DIRECTIONS.
C
  DATA ARRANGEMENT ON NUTMX, NUTKX, NUTLT, NUTST FOR EACH FINITE
C
  ELEMENT IS (W=M,K,LT,ST)
C
      WRITE (NUTWX) NAMEW, NEL, NR, NC, NAMEL, (IBLNK, I=1,5),
C
                    ({W(I,J),I=1,NP),J=1,NC),(IVEC(I),I=1,NC)
  CALLS FORMA SUBROUTINES MASSA, PAGEND, STF3A, ZZBOMB.
C
  DEVELOPED BY PL WOHLEN. APRIL 1974.
C
  LAST REVISION BY WA PENFIELD. MARCH 1976.
C
C
  C
  INPUT DATA READ IN THIS SUPROUTINE FROM NUTEL. IF NUTEL = 5, DATA IS
C
   READ FROM CARDS.
C
     NAMEM, NAMEK, NAMELT, NAMEST
                                                  FORMAT (4(A6,4X)
C
                                                  FORMAT (2(5x,E10))
      PD.G
                                                  FORMAT (2(5X,E10))
C
      TMAS, TSTE
                                                  FORMAT (515)
   20 NEL, J1, J2, J3, J4
C
C
      IF (JI .FQ. O) RETURN
      GO TO 20
C
C
   DEFINITION OF INPUT VARIABLES.
   NAMEM = TYPE OF MASS MATRIX WANTED.
```

```
= MI, DIAGONAL LUMPED.
           = M2, CONSISTENT.
C
C
            = 6H
                       OR 6HNOMASS, NO MASS MATRIX CALCULATED.
C
   NAMEK
         = TYPE OF STIFFNESS MATPIX WANTED.
C
            = KI, LIMEAR DISPLACEMENT (CONSTANT STRAIN).
C
                       OR 6HNCSTIF, NO STIFFNESS MATRIX CALCULATED.
            = 6H
C
   NAMELT = IDFNTIFICATION NAME FOR LOAD TRANSFORMATION MATRICES.
C
                       OR 6HNOLDAD, NO LOAD TRANSFORMATIONS CALCULATED.
            - 6H
C
   NAMEST = IDENTIFICATION NAME FOR STRESS TRANSFORMATION MATRICES.
C
            = 6H
                       OR 6HNOSTRS, NO STRESS TRANSFORMATIONS CALCULATED.
C
  RD
          = MASS DENSITY.
C
         = SHEAR MODULUS OF ELASTICITY.
C
   TMAS
         = EFFECTIVE MASS
                               THICKNESS.
C
   TSTF
          = EFFECTIVE STIFFNESS THICKNESS.
C
   NEL
         = FINITE ELEMENT NUMBER. FOR REFERENCE ONLY. NOT USED IN
C
            CALCULATIONS. WRITTEN ON NUTMX. ETC.
C
         = JOINT NUMEER AT PANEL VERTEX 1.
   JI
C
          = JUINT NUMBER AT PANEL VERTEX 2.
   J2
          = JOINT NUMBER AT PANEL VERTEX 3.
C
   J3
          = JOINT NUMBER AT PANEL VERTEX 4.
C
   J4
C
   EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C
      I = INTEGEF DATA, RIGHT ADJUSTED.
C
      E = DECIMAL POINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED.
C
      X = CARD COLUMNS SKIPPED.
C
C
   C
C
      SUBROUTINE ARGUMENTS (ALL INPUT)
C
   XYZ
          = MATRIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWS CORRESPOND
C
            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C
            X,Y,2 LOCATIONS RESPECTIVELY. SIZE(NJ,3).
          = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND
C
   JDCF
C
            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C
            TRANSLATION DOFS AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
C
            RUTATION DOFS. SIZE (NJ.61.
C
   EUL
          = MATPIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND
C
            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
C
            GLCHAL X,Y,Z PERMUTATION. SIZF(NJ,3).
C
         = LOGICAL NUMBER OF TAPE CONTAINING ELEMENT INPUT DATA FOR
   NUTEL
C
            THIS SUPPOUTINE. IF NUTEL = 5, DATA IS READ FROM CARDS.
C
          = NUMBER OF JOINTS OR ROWS IN MATRICES (XYZ), (JDDF), (EUL).
Ĉ
   NUTMX
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C
            MASS MATRICES AND IVECS ARE DUTPUT.
C
            NUTMY MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C
            USES FORTRAN PEAD, WRITE.
         = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C
   NUTKX
            STIFFNESS MATPICES (SAME AS GLOBAL LOADS TRANSFORMATION
C
C
            MATRICES) AND I VECS ARE CUTPUT.
C
            NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C
            USES FORTRAN PEAD, WRITE.
C
   NUTET = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOCAL
C
            LOAD TRANSFERMATION MATRICES AND IVECS ARE OUTPUT.
            NUTLY MAY BE ZEFO IF LOAD TRANSFORMATIONS ARE NOT FORMED.
C
C
            USES FORTKAN READ, WRITE.
   NUTST = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
```

```
STRESS TRANSFORMATION MATRICES AND IVECS ARE CUTPUT.
            NUTST MAY BE ZERO IF STRESS TRANSFORMATIONS ARE NOT FORMED.
            USES FORTRAN READ, WRITE.
C
C
   W
          = MATFIX WORK SPACE. MIN SIZE(12,12).
C
          = MATFIX WOFK SPACE. MIN SIZE(12,12).
C
   S
          = MATPIX WORK SPACE. MIN SIZE(12,12).
          = ROW DIMENSION OF XYZ IN CALLING PROGRAM.
C
   KX
          = POW DIMENSION OF JOOF IN CALLING PROGRAM.
C
  KJ
          = POW DIMENSION OF EUL IN CALLING PROGRAM.
C
  KE
          = ROW DIMENSION OF W. T. AND S IN CALLING PROGRAM. MIN=12.
C
  KW
C
C
      NERROR EXPLANATION
  1 = INPUT JOINT NUMBER EXCEEDS MAXIMUM ALLOWABLE NUMBER OF JOINTS.
   2 = NUTMX NON POSITIVE.
   3 = NUTKX NON POSITIVE.
   4 = NUTLT NON POSITIVE.
   5 = NUTST NON POSITIVE.
 1001 FORMAT (4(A6,4X))
 1002 FORMAT (2(5X,E10.0))
 1003 FOPMAT (515)
 2001 FORMAT (//38X 47HINPUT DATA FOR RECTANGULAR SHEAR PANEL ELEMENTS)
 2002 FORMAT (//32X 47HINPUT DATA FOR RECTANGULAR SHEAR PANEL ELEMENTS
                     12H (CONTINUED))
 2003 FORMAT (/ 14X7HMASS = A6, 14X7HSTIF = A6, 11X13HLOAD TRANS = A6,
                8X15HSTRESS TRANS = A6,
     *
              / 16X4PRO = E10.3, 14X3PG = E10.3,
     *
               / 11X9HT (MASS) = E10.3, 8X9HT (STIF) = E10.3,
               //18x7HELEMENT 13x7HJCINT 1 13x7HJOINT 2 13x7HJOINT 3
                13X7HJCINT 4 / 18X6HNUMBER1
 2004 FORMAT (18X,5(15,15X))
C
   READ AND WRITE FINITE ELEMENT DATA.
C
      NLINE = 0
      CALL PAGEED
      WRITE (NOT, 2001)
      READ (NUTFL, 1001) NAMEM, NAMEK, NAMELT, NAMEST
      READ (NUTFL,1002) RC,G
      READ (NUTEL, 1002) TMAS, TSTF
      WRITE (NOT, 2003) NAMEM, NAMEK, NAMELT, NAMEST, RO, G, TMAS, TSTF
   20 READ (NUTFL, 1603) NEL, J1, J2, J3, J4
      IF (JI .LE. O) RETURN
      NLINF = NLINF + 1
      IF (NLINE .LE. 42) GO TO 30
      CALL PAGEED
      WRITE (NCT, 2002)
      WRITE (NOT, 2003) NAMEM, NAMEK, NAMELT, NAMEST, RO, G, TMAS, TSTE
      NLINE = 0
   30 WRITE (NCT,2004) NEL, J1, J2, J3, J4
                                                                   NERROR=1
      IF (J1.G7.NJ .OR. J2.GT.NJ .OR. J3.GT.NJ .OR. J4.GT.NJ) GO TO 999
   FORM FINITE FLEMENT COORDINATE LOCATIONS, EULER ANGLES, REVADD IVEC.
      DO 42 1=1.3
      CJ(I,I) = YYZ(JI,I)
```

```
CJ(1,2) = XYZ(J2,1)
      CJ(1,3) = XYZ(J3,1)
      CJ(I,4) = XYZ(J4,I)
      EJ(I,1) = FUL(JI,1)
      EJ(1,2) = FUL(J2,1)
      EJ(1,3) = EUL(J3,I)
   42 EJ(I,4) = FUL(J4,1)
      DC 44 I=1,3
      1V1(1) = JD0F(J1,1)
      IV1(I+3) = JDOF(J2,I)
      IVI(I+6) = JDCF(J3,I)
   44 \text{ IV1}(I+9) = JDDF(J4,1)
   FORM MASS MATRIX (W).
      IF (NAMEM .EQ. 6H
                               .CR. NAMEM .EQ. 6HNCMASS) GO TO 110
      CALL MASSA (CJ,EJ,TMAS,RO,NAMEM,W,T,S,KCJ,KCJ,KW,XW,KW)
                                                                  NERROR=2
      IF (NUTMX .LE. 0) GO TO 999
      WRITE (NUTMX) NAMEM, NFL, NRW, NRW, NAMEL, (IBLNK, I=1,5),
                     ((W(I,J),I=1,NRW),J=1,NRW),(IV1(I),I=1,NRW)
C
   FORM STIFFNESS MATRIX (W), LOCAL LOAD TRANSFORMATION MATRIX (T),
   STRESS TRANSFORMATION MATRIX (S).
                            .CR. NAMEK .EQ. 6HNOSTIF) GO TO 20
  110 IF (NAMEK .EQ. 6H
      CALL STF3A (CJ,EJ,TSTF,G,NAMEK,NAMEST,W,T,S,NRST,
                   KCJ, KCJ, KW, KW, KW)
                                                                  NERROR=3
      IF (NUTKX .LE. 0) 60 TO 999
      WRITE (NUTKX) NAMEK, NEL, NRW, NRW, NAMEL, (IBLNK, I=1,5),
                     {(W{I,J},I=1,NRW),J=1,NRW),(IV1(I),I=1,NRW)
      IF (NAMELT .EQ. 6H
                                .OR. NAMELT .EQ. 6HNOLOAD) GO TO 115
                                                                  NERROR=4
      IF (NUTLT .LE. C) 60 TO 999
      WRITE (NUTLI) NAMELT, NEL, NRLT, NRW, NAMEL, (IBLNK, I=1,5),
                     ((T(1,J),I=1,NRLT),J=1,NRW),(IV1(I),I=1,NRW)
  115 IF (NAMEST .EG. 6H
                                .OP. NAMEST .EQ. 6HNOSTRS) GO TO 20
                                                                  NERROR=5
      IF (NUTST .LE. 0) GC TC 999
      WRITE (NUTST) NAMEST, NEL, NRST, NRW, NAMEL, (IBLNK, I=1,5),
                     ((S(I,J),I=1,NRST),J=1,NRW),(IV1(I),I=1,NRW)
      GC TO 20
  999 CALL ZZBOME (6HRECTSP, NERROR)
      END
```

```
SUBROUTINE STEIA
                        (CJ,EJ,A1,A2,E,NAMEK,NAMEST,S,TL,TS,NRST,
                         KCJ, KEJ, KS, KTL, KTS)
      UIMENSION CJ(KCJ,1), EJ(KEJ,1), S(KS,1), TL(KTL,1), TS(KTS,1)
C
   SUBROUTINE TO CALCULATE FINITE ELEMENT ...
C
      STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION MATRIX),
C
      LOCAL LOAD TRANSFORMATION MATRIX.
      STRESS TRANSFORMATION MATRIX.
C
C
   FOR AN AXIAL ROD FLEMENT WITH UNRESTRAINED BOUNDARIES.
   ROD MAY BE LINEARLY TAPERED OR UNIFORM.
C
   STIFFNESS MATRIX IS IN GLOBAL COCRDINATE DIRECTIONS.
C
C
   GLOBAL COORDINATE ORDER IS
      (U,V,W) JOINT 1, THEN JOINT 2.
C
   WHERE U, V, W ARE TRANSLATIONS.
C
   GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT ROD ENDS IN GLOBAL
C
   COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C
C
   DIRECTIONS.
   ROW ORDER IN GLOEAL LOAD TRANSFORMATION MATRIX IS
C
C
      (PU.PV.PW) JCINT 1, THEN JOINT 2.
C
   WHERE P IS FORCE.
   LOCAL LOAD TPANSFORMATION MATRIX PELATES LOADS AT FOD ENDS IN LOCAL
C
   COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C
   ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS
C
C
      PX1,PX2
C
   WHERE PX IS AXIAL FORCE.
   PX1(-), PX2(+) IS TENSION. PX1(+), PX2(-) IS COMPRESSION.
C
   STRESS TRANSFORMATION MATRIX RELATES STRESS AT FOD ENDS IN LOCAL
C
   COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C
   ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C
C
      SIGMA-X1, SIGMA-X2
   WHERE SIGMA IS NORMAL STRESS.
C
   SX1(-), SX2(+) IS TENSION. SX1(+), SX2(-) IS COMPRESSION.
C
C
   EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
   CALLS FORMA SUPPOUTINES ATXBAI, DOOSIA, KIAI, MULTA, ZZEOMB.
C
C
   DEVELOPED BY RL WOHLEN. SEPTEMBER 1972.
C
   LAST REVISION BY WA BENFIELD. MARCH 1976.
C
C
      SUBROUTINE ARGUMENTS
                   MATRIX OF GLOBAL X,Y,Z COORDINATES AT ROD JOINTS.
C
   CJ
          = INPUT
                   ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C
                   COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).
C
                   MATRIX OF FULEP ANGLES (DEGREES) AT ROD JOINTS.
C
   EJ
          = INPUT
                   RCWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C
                   COLS 1,2 CORRESPOND TO JOINTS 1,2. SIZE(3,2).
C
C
                   CROSS-SECTION ARFA AT POD END 1.
          = INPUT
   A1
                   CRUSS-SECTION AREA AT ROD END 2.
C
          = INPUT
   A2
C
          = INPUT
                   YOUNGS MODULUS OF ELASTICITY.
   F
C
         = IMPUT
                   TYPE OF STIF MATRIX WANTED.
   NAMEK
                   = K1, CONSTANT AXIAL FORCE ASSUMED.
C
   NAMEST = INPUT
                   CPTION FOR STRESS TRANSFORMATION.
C
                              OR 6HNOSTRS ,NO STRESS TRANS CALCULATED.
C
C
          = OUTPUT STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION
C
                   MATRIX). $12E(6,6).
          = OUTPUT LOCAL LOAD TRANSFORMATION MATRIX. SIZE(2,6).
C
   TL
C
   TS
          = QUTPUT STRESS TRANSFORMATION MATRIX. SIZE(NRST,6).
```

```
NRST
         = OUTPUT NUMBER OF ROWS IN STRESS TRANSFORMATION MATRIX.
  KCJ
         = INPUT ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
                  ROW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
Ċ
         = INPUT
  KEJ
                  ROW DIMENSION OF S IN CALLING PROGRAM. MIN=6.
C
         = IMPUT
  KS
                  FOW DIMENSION OF TL IN CALLING PROGRAM. MIN=2.
          = INPUT
  KTL
                   FOW DIMENSION OF TS IN CALLING PROGRAM. MIN=NRST.
C
  KTS
          = INPUT
      NERROR EXPLANATION
  1 = SIZE LIMITATION EXCEEDED.
   2 = NAMEK IMPROPERLY DEFINED.
      NRST = 2
                                                                NERROR=1
      IF (KS .LT. 6 .OR. KTL .LT. 2 .OR. KTS .LT. NRST) GO TO 999
     RL = SGPT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
                                     + (CJ(3,2)-CJ(3,1))**2)
                             ) GO TO 110
      IF (NAMEK .FQ. 6HK1
                                                                NERROR=2
      GD TO 999
  110 CALL KIA1
                                                                        TL=K
                (A1,A2,RL,E,TL,TS,KTL,KTS)
C
                                                                        S=DC
      CALL DEGSIA (CJ,EJ,S,KCJ,KEJ,KS)
      CALL MULTA (11,5, 2,2,6, KTL,KS)
      IF (NAMEST .EQ. 6P
                           .OR. NAMEST .EQ. 6HNOSTRS) GO TO 210
      CALL MULTA (TS,S,NRST,2,6, KTS,KS)
  210 CALL ATXBA1 (S.TL. 2.6, KS.KTL)
      RETURN
  999 CALL ZZBOMB (6HSTF1A .NERPOR)
      END
```

```
(CJ,EJ,KODE,A1,A2,TJ1,TJ2,BIZ1,BIZ2,BIY1,BIY2,
      SUPRCUTINE STF18
                          R1,R2,CY1,CY2,CZ1,CZ2,SF,E,G,NAMEK,NAMEST,
     *
                          S, TL, TS, NRST, KCJ, KEJ, KS, KTL, KTS)
      DIMENSION CJ(KCJ,1),EJ(KEJ,1),KODE(1),S(KS,1),TL(KTL,1),TS(KTS,1)
C
C
   SUBROUTINE TO CALCULATE FINITE ELEMENT ...
      STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION MATRIX),
C
C
      LOCAL LOAD TRANSFORMATION MATRIX,
C
      STRESS TRANSFORMATION MATPIX.
   FOR A COMBINED AXIAL-TORSION-BENDING BAR ELEMENT WITH UNRESTRAINED
   BOUNDARIES.
C
   BAR MAY BE LINEARLY TAPERED OR UNIFORM.
C
   STIFFNESS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
C.
   GLOBAL COOPDINATE ORDER IS
C
      (U, V, W, P, Q, R) JOINT 1, THEN JOINT 2
   WHERE U, V, W ARE TRANSLATIONS AND P,Q,R ARE ROTATIONS.
   GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT BAR ENDS IN GLOBAL
C
   COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C
ũ
   DIRECTIONS.
   KOW ORDER IN GLOEAL LOAD TRANSFORMATION MATRIX IS
      (PU, PV, PW, MP, MQ, MR) JOINT 1, THEN JOINT 2.
   WHERE P IS FORCE AND M IS MOMENT.
   LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT BAR ENDS IN LOCAL
   COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
   ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS
C
      PX1,PX2,MX1,MX2,PY1,PY2,MZ1,MZ2,PZ1,PZ2,MY1,MY2
C
C
   WHERE P IS FORCE AND M IS MOMENT.
   STRESS TRANSFORMATION MATRIX RELATES STRESS AT BAR ENDS IN LOCAL
C
   COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
C
C
   ROW ORDER IN STRESS TRANSFORMATION MATRIX IS
C
      PX1/A1,PX2/A2,
                         MX1 *R 1/TJ1, MX2*R2/TJ2,
      PY1/A1, PY2/A2, MZ1 *CY1/B1Z1, MZ2 *CY2/B1Z2,
C
      PZ1/A1, PZ2/A2, MY1*CZ1/BIY1, MY2*CZ2/BIY2
C
   WHERE P IS FORCE AND M IS MOMENT.
C
   EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
   CALLS FORMA SUBROUTINES ATXBA1, DCOS1B, K1A1, K1B1, K1C1, MULTA, ZZBOMB.
C
   DEVELOPED BY RL WOHLEN. FEBRUARY 1973.
C
   LAST REVISION BY RL WOHLEN. APRIL 1976.
C
      SUBROUTINE ARGUMENTS
C
   CJ
                   MATRIX OF GLOBAL X,Y,Z COORDINATES AT RAR JOINTS.
C
          = INPUT
                   ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C
                    COLS 1,2 CORRESPOND TO JOINTS 1,2. COL 3 CORRESPONDS
C
C
                    TO REFERENCE POINT TO DEFINE LOCAL XY PLANE. SIZE(3,3).
C
                   MATRIX OF EULER ANGLES (DEGREES) AT BAR JOINTS.
   FJ
          = INPUT
                    ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C
C
                    COLS 1,2 CORPESPOND TO JOINTS 1,2. SIZE(3,2).
                   OPTION CODE FOR AXIAL, TORSION, BENDING 2, BENDING Y
C
   KODE
          = INPUT
C
                    LPCAL STIFFNESS. IF BLANK, ALL FOUR ARE CALCULATED.
C
                    SIZE (4).
                    KODE (1)=A , LOCAL STIFFNESS MATRIX IS CALCULATED
C
C
                                FOR AXIAL (ALONG LOCAL X-AXIS).
                    KCDE(2)=T , LOCAL STIFFNESS MATRIX IS CALCULATED
C
C
                                FOR TORSION (ABOUT LOCAL X-AXIS).
                    KODE (3)=BZ, LOCAL STIFFNESS MATRIX IS CALCULATED
```

```
C
                                FOR BENDING (ABOUT LOCAL Z-AXIS).
C
                   KUDE (4)=BY, LUCAL STIFFNESS MATRIX IS CALCULATED
C
                                FOR BENDING (ABOUT LOCAL Y-AXIS).
                   CROSS-SECTION AREA AT BAR END 1.
C
   A1
          = INPUT
                   SAME AS AT AT BAR END 2.
C
          = IMPUT
   A2
                   CROSS-SECTION SAINT VENANTS TORSION CONSTANT (J) IN
C
          = INPUT
   TJI
                    JG AT BAR END 1.
C
          = INPUT
                   SAME AS TJ1 AT BAR END 2.
   TJ2
                   CPOSS-SECTION AREA MOMENT OF INERTIA ABOUT LOCAL
C
          = INPUT
   BIZ1
                   Z-AXIS (FOR BENDING) AT BAR END 1.
C
   BIZ2
          = INPUT
                   SAME AS BIZ1 AT EAR END 2.
C
   BIY1
          = INPUT
                   CROSS-SECTION AREA MOMENT OF INERTIA ABOUT LOCAL
                    Y-AXIS (FOR BENDING) AT BAR END 1.
C
   SYIS
          = INPUT
                   SAME AS BIY1 AT BAR END 2.
                   DISTANCE FROM LOCAL X-AXIS TO OUTER FIBER FOR
C
   R1
          = INPUT
                    TORSION STRESS CALCULATION AT BAR END 1.
C
   R2
          = INPUT
                   SAME AS RI AT BAR END 2.
C
   CY1
          = INPUT
                   DISTANCE FROM XZ PLANE TO OUTER FIBER FOR BENDING
C
                   STRESS CALCULATION AT BAR END 1. LOCAL Y DIRECTION.
C
   CY2
          = INPUT
                   SAME AS CY1 AT BAR END 2.
C
   CZI
          = INPUT
                   DISTANCE FROM XY PLANE TO DUTER FIBER FOR BENDING
                   STRESS CALCULATION AT BAR FND 1. LOCAL Z DIRECTION.
C
C
          = INPUT
   CZ2
                   SAME AS CZ1 AT BAR END 2.
                    SHAPE FACTOR (K) FOR SHEAR IN KAG.
C
   SF
          = INPUT
                   USE SE=0.0 FOR NO SHEAR DEFORMATION IN BENDING.
C
                   SF=1.0 FCR A SCLID CIRCULAR CYLINDER.
C
C
                   SF=.5 FOR A THIN WALLED CIRCULAR CYLINDER.
                   YOUNGS MODULUS OF ELASTICITY.
C
   E
          = INPUT
                    SHEAR MODULUS OF ELASTICITY.
C
          = IMPUT
                   TYPE OF STIF MATPIX WANTED.
C
   NAMEK
         = INPUT
                    = K1, USES K1A1 FOR AXIAL, K1C1 FOR TORSION,
                          KIBI FOR BENDING.
C
  NAMEST = INPUT
                   OPTION FOR STRESS TRANSFORMATION.
C
                               OR 6HNOSTRS .NO STRESS TRANS CALCULATED.
C
                   = 6H
C
   S
          = OUTPUT STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION
C
                   MATRIX). SIZE(12,12).
          = OUTPUT LOCAL LOAD TRANSFORMATION MATRIX. SIZE(12,12).
C
   TI
          = DUTPUT STRESS TRANSFORMATION MATRIX. SIZE(NRST,12).
C
   TS
          = CUTPUT NUMBER OF ROWS IN STRESS TRANSFORMATION MATRIX.
C
   NRST
                   POW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C
   KCJ
          = IMPUT
                   FOW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
C
   KEJ
          = INPUT
                   ROW DIMENSION OF S IN CALLING PROGRAM. MIN=12.
C
   KS
          = IMPUT
                   ROW DIMENSION OF TL IN CALLING PROGRAM. MIN=12.
C
   KTL
          = INPUT
                   ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=NRST.
C
   KTS
          = INPUT
C
      NEPROF
             EXPLANATION
   1 = SIZE LIMITATION EXCEEDED.
C
   2 = NAMEK IMPROPERLY DEFINED.
C
C
      NRST = 12
                                                                  NERROR=1
      IF (KS .LT. 12 .OF. KTL .LT. 12 .OF. KTS .LT. NRST) GO TO 999
      DO 5 J=1,12
      DC 5 1=1,12
```

TL(I,J) = 0.0

```
5 TS(I,J) = 0.0
      RL = SQRT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
                                       + (CJ(3,2)-CJ(3,1))**2)
      KODEA = 1
      KODET = 1
      KODEBZ = 1
      KODEBY = 1
      IF (KODE(1).EQ.1H .AND. KODE(2).EQ.1H
                                                 - AND -
          KODE (3).EQ.2H .AND. KODE (4).EQ.2H ) GO TO 10
      IF (KCDE(1) \cdot NE \cdot 1HA) \cdot KODEA = 0
      IF (KODE(2) \cdot NE \cdot IHT) KODET = 0
  LAST HALF OF NEXT TWO CARDS ALLOW FOR OLD DATA. INSERTED APRIL 1976.
      IF (KCDE(3) \cdot NE \cdot 2HBZ \cdot AND \cdot KODE(3) \cdot NE \cdot 2HBY) KODEBZ = 0
      IF (KODE(4) \cdot NE \cdot 2HBY \cdot AND \cdot KODE(4) \cdot NE \cdot 2HBZ) KODEBY = 0
                              ) GO TO 110
   10 IF (NAMEK .EQ. 6HK1
                                                                      NERROR=2
      GO TO 999
C
   AXIAL = KIA1 (CONSTANT FORCE), TORSION = K1C1 (CONSTANT TORQUE),
  BENDING = KIBI (CONSTANT SHEAR, LINEAR BENDING MOMENT).
  110 IF (KODEA .FG. 1) CALL KIAI (AI,A2,RL,F,TL,TS,KTL,KTS)
      IF (KODET .EQ. 1) CALL K1C1 (TJ1,TJ2,R1,R2,RL,G,TL(3,3),TS(3,3),
     *
                                       KTL,KTS)
      IF (KODEBZ .EQ. 1) CALL K181 (BIZ1, BIZ2, CY1, CY2, A1, A2, SF, RL, E, G,
                                       TL(5,5),TS(5,5),KTL,KTS)
      DO 115 J=7,8
      DO 115 I=5,6
      TL(I,I) = -TL(I,J)
      TS(I,J) = -TS(I,J)
      TL(J,I) = -TL(J,I)
  115 TS(J,1) = -TS(J,1)
      IF (KCDEBY .EQ. 1) CALL K1R1 (RIY1, BIY2, CZ1, CZ2, A1, A2, SF, RL, E, G,
                                       TL(9,9),TS(9,9),KTL,KTS)
                                                                              TL=K
C
      CALL DOUSIB (CJ,EJ,S,KCJ,KEJ,KS)
                                                                              S=DC
      CALL MULTA (TL,S, 12,12,12, KTL,KS)
      IF (NAMEST .FC. 6H
                                 •OR. NAMEST •EQ. 6HNOSTRS) GO TO 210
      CALL MULTA (TS,S,NRST,12,12, KTS,KS)
  210 CALL ATXEAL (5,TL, 12,12, KS,KTL)
      RETURN
  999 CALL ZZEGME (6HSTF1B ,NERROR)
      END
```

```
SUBROUTINE STF2
                        (CJ, EJ, TMEM, T'EN, E, ANU, NAMEK, NAMEST, S, TL, TS, NR ST,
                        KCJ, KEJ, KS, KTL, KTS)
      DIMENSION CJ(KCJ,1), EJ(KEJ,1), S(KS,1), TL(KTL,1), TS(KTS,1)
   SUBROUTINE TO CALCULATE FINITE ELEMENT ...
C
      STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION MATRIX),
C
      LOCAL LOAD TRANSFORMATION MATRIX,
C
      STRESS TRANSFORMATION MATRIX,
   FOR A COMBINED MEMBRANE-BENDING TRIANGLE PLATE ELEMENT WITH
C
   UNRESTRAINED FOUNDARIES.
   STIFFNESS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
   GLORAL COORDINATE ORDER IS
C
      (U,V,W,P,Q,R) JOINT 1, THEN JOINT 2, 3.
   WHERE U, V, W ARE TRANSLATIONS AND P, Q, R ARE POTATIONS.
C
C
   GLOBAL LOAD TRANSFORMATION MATFIX RELATES LOADS AT TRNGL VERTICES IN
   GLOBAL COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C
C
   DIRECTIONS.
   ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C
C
      (PU, PV, PW, MP, MQ, MR) JOINT 1, THEN JOINT 2,3.
C
   WHERE P IS FORCE AND M IS MOMENT.
   LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT TRNGL VERTICES IN
C
C
   LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
C
   DIRECTIONS.
C
   ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS
C
      (PX, PY, MZ) JOINT 1 THEN 2,3, NEXT
C
      (PZ,MX,MY) JOINT 1 THEN 2,3.
C
   WHERE P IS FORCE AND M IS MOMENT.
C
   STRESS TRANSFORMATION MATRIX RELATES STRESS AT TRNGL VERTICES IN LOCAL
C
   COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTIONS.
   ROW ORDER IN STRESS YRANSFORMATION MATRIX IS
C
      (SIGMA-X, SIGMA-Y, TAU-XY) FOR (Z=TBEN/2) AT JOINT 1.
C
C
      THEN JOINT 2,3.
      (SIGMA-X, SIGMA-Y, TAU-XY) FOR (Z=-TBEN/2) AT JOINT 1,
C
C
      THEN JOINT 2,3.
   WHERE SIGMA IS NORMAL STRESS AND TAU IS SHEAR STRESS.
C
   EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
C
   CALLS FORMA SUBROUTINES ATXBAI, DCOS2, K2A1, K2B1, MULTA, ZZBOMB.
   DEVELOPED BY WA BENFIELD. FEBRUARY 1973.
C
C
   LAST REVISION BY WA BENFIELD. MARCH 1976.
C
C
      SUBROUTINE ARGUMENTS
C
   CJ
                   MATRIX OF GLOEAL X,Y,Z COOPDINATES AT TRIANGLE JOINTS.
          = INPUT
C
                    RCWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
C
                    COLS 1,2,3 CORRESPOND TO JOINTS 1,2,3. SIZE(3,3).
C
          = INPUT
                   MATRIX OF EULER ANGLES (DEGREES) AT TRIANGLE JOINTS.
   EJ
C
                    POWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
                    CCLS 1,2,3 CCRRESPOND TO JOINTS 1,2,3. SIZE(3,3).
C
C
   TMEM
          = IMPUT
                   EFFECTIVE MEMBRANE THICKNESS.
C
          = INPUT
                   EFFECTIVE BENDING THICKNESS.
   THEN
C
                    YOUNGS MODULUS OF ELASTICITY.
   E
          = INPUT
C
   ANU
          = INPUT
                   PRISSONS RATIO. (E/2G)-1.
C
          = INPUT
                    TYPE OF STIF MATRIX WANTED.
   NAMEK
C
                    = K1, USFS K2A1 FOR MEMBRANE, K2B1 FOR BENDING.
C
   NAMEST = INPUT
                   OPTION FOR STRESS TRANSFORMATION.
C
                    = 6H
                               OR 6HNOSTRS , NO STRESS TRANS CALCULATED.
```

```
= OUTPUT STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION
C
                   MATRIX). SIZE(18,18).
  TL
          = OUTPUT LCCAL LOAD TRANSFORMATION MATRIX. SIZE(18,18).
          = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(NRST, 18).
C
   TS
          = OUTPUT NUMBER OF ROWS IN STRESS TRANSFORMATION MATRIX.
  NRST
          = INPUT
                   ROW DIMENSION OF CJ IN CALLING PROGRAM.
С
  KCJ
                   ROW DIMENSION OF EJ IN CALLING PROGRAM.
C
  KEJ
          = INPUT
                   POW DIMENSION OF S IN CALLING PROGRAM. MIN=18.
C
  KS
          = INPUT
                   ROW DIMENSION OF TL IN CALLING PROGRAM. MIN=18.
   KTL
          = INPUT
                   ROW DIMENSION OF TS IN CALLING PROGRAM. MINENRST.
   KTS
          = INPUT
C
      NERROR EXPLANATION
   1 = SIZE LIMITATION EXCEEDED.
   2 = NAMEK IMPROPERLY DEFINED.
      NRST = 18
                                                                  NERROR=1
      IF (KS .LT. 18 .OR. KTL .LT. 18 .OR. KTS .LT. NRST) GO TO 999
      DO 5 J=1,18
      D0 5 I=1,18
      TL(I,J) = 0.0
    5 TS(1,J) = 0.0
      SL12 = SQRT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
                                        + (CJ(3,2)-CJ(3,1))**2)
      SL23 = SQRT((CJ(1,3)-CJ(1,2))**2 + (CJ(2,3)-CJ(2,2))**2
                                        + (CJ(3,3)-CJ(3,2))**2)
      SL13 = SQR1((CJ(1,3)-CJ(1,1)) **2 + (CJ(2,3)-CJ(2,1)) **2
                                        + (CJ(3,3)-CJ(3,1))**2)
           = (SL13**2+SL12**2-SL23**2)/(2.0*SL12)
           = SQRT(SL13**2-X3**2)
      IF (NAMEK .EQ. 6HK1 ) GO TO 110
                                                                  NERROR=2
      GD TC 999
                                                                    .
C
   MEMBRANE = K2A1 (BODLEY, BENFIELD), FENDING = K2B1 (BODLEY).
                  (SL12,X3,Y3,TMEM,F,ANU,TL,TS,S,KTL,KTS,KS)
                                                                          TL=K
  110 CALL K2A1
      CALL K2B1
                  (SL12, X3, Y3, TBEN, E, ANU, TL (10, 10), TS(1, 10), S,
                   KTL, KTS, KS)
      DO 111 I=1,9
      II = I+9
      DC 111 J=1.9
  111 TS(II,J) = TS(I,J)
C
      CALL DCOS2 (CJ,EJ,S,KCJ,KEJ,KS)
                                                                          S=DC
      CALL MULTA
                 (TL,S,18,18,18,KTL,KS)
      IF (NAMEST .EQ. 6H
                               .OR. NAMEST .EQ. 6HNOSTRS) GO TO 210
      CALL MULTA (TS,S,NRST,18,18,KTS,KS)
  210 CALL ATXBA1 (S,TL,18,18,KS,KTL)
      RETURN
  999 CALL ZZBOMB (5HSTF2 , NERROR)
      END
```

```
SUBROUTINE STE3 (CJ, EJ, TMEM, TBEN, E, ANU, NAMEK, NAMEST, S, TL, TS, NR ST,
                     KCJ,KEJ,KS,KTL,KTS)
   DIMENSION CJ(KCJ,1),EJ(KEJ,1),S(KS,1),TL(KTL,1),TS(KTS,1)
   DIMENSION CW(3,3), EW(3,3), W1(18,18),
             IVI(18), IV2(18), IV3(18), IV4(18)
   DATA KCW, KW1 / 3,18 /
   DATA IV1/ 1, 2, 3, 4, 5, 6, 7, 8, 9,10,11,12,13,14,15,16,17,18/,
        1\(\frac{1}{2}\) 1, 2, 3, 4, 5, 6, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24/,
        1V3/ 1, 2, 3, 4, 5, 6, 7, 8, 9,10,11,12,19,20,21,22,23,24/,
        1V4/ 7, 8, 9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24/
SUBROUTINE TO CALCULATE FINITE ELEMENT...
   STIFFNESS MATRIX (SAME AS GLORAL LOAD TRANSFORMATION MATRIX),
   LOCAL LOAD TRANSFORMATION MATRIX (NOT YET).
   STRESS TRANSFORMATION MATRIX (NOT YET),
FOR A COMEINED MEMBRANE-BENDING QUADRILATERAL PLATE ELEMENT WITH
UNRESTRAINED ROUNDARIES.
STIFFNESS MATRIX IS IN GLUBAL COORDINATE DIRECTIONS.
GLOBAL COORDINATE ORDER IS
   (U, V, W, P, Q, R) JOINT 1, THEN JOINT 2, 3, 4.
WHERE U, V, W ARE TRANSLATIONS AND P,Q, R ARE ROTATIONS.
GLOBAL LOAD TRANSFORMATION MATRIX PELATES LOADS AT QUAD VERTICES IN
GLOBAL COORDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
DIRECTIONS.
ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
   (PU, PV, PW, MP, MQ, MR) JOINT 1, THEN JOINT 2,3,4.
WHERE P IS FORCE AND M IS MUMENT.
LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT QUAD VERTICES
IN LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
DIRECTION.
STRESS TRANSFORMATION MATRIX RELATES STRESS AT QUAD VERTICES IN LOCAL
COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE DIRECTION.
EULER ANGLE CONVENTION IS GLOBAL X,Y,Z PERMUTATION.
CALLS FORMA SUBROUTINES STF2, REVADD, ZZBOMB.
DEVELOPED BY WA BENFIELD, RL WOHLEN. FEBRUARY 1973.
LAST REVISION BY WA BENFIELD. MARCH 1976.
   SUPPOUTINE ARGUMENTS
CJ
       = INPUT
                MATRIX OF GLOBAL X,Y,2 COORDINATES AT QUAD JOINTS.
                ROWS 1,2,3 CORRESPOND TO X,Y,Z COURDINATES.
                COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
       = INPUT
                MATRIX OF EULFR ANGLES (DEGREES) AT WUAD JOINTS.
ΕJ
                POWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
                COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. $12E(3,4).
                EFFECTIVE MEMBRANE THICKNESS.
TMEM
       = INPUT
                EFFECTIVE BENDING THICKNESS.
TREN
       = INPUT
                YOUNGS MODULUS OF ELASTICITY.
       = IMPUT
Ε
ANU
       = INPUT
                POISSONS RATIO. (E/2G)-1.
      = INPUT
                TYPE OF STIF MATRIX WANTED.
NAMEK
                = K1, USES 4 TRIANGLES, OVERLAP AVERAGE.
                OPTION FOR STRESS TRANSFORMATION.
NAMEST = INPUT
                            OR CHNOSTRS , NO STRESS TRANS CALCULATED.
       = OUTPUT STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION
                MATRIX). SIZF(24,24).
TL
       = OUTPUT LUCAL LOAD TRANSFORMATION MATRIX. SIZE(24,24).
```

C

C

C

C

C

C

C

C.

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

```
= OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(NRST,24).
C
   TS
          = OUTPUT NUMBER OF FOWS IN STRESS TRANSFORMATION MATRIX.
C
   NRST
£
   KCJ
          = IMPUT
                    ROW DIMENSION OF CJ IN CALLING PROGRAM. MIN=3.
C
                    POW DIMENSION OF EJ IN CALLING PROGRAM. MIN=3.
   KEJ
          = INPUT
C
          = INPUT
                    RUW DIMENSION OF S IN CALLING PROGRAM. MIN=24.
   KS
          = INPUT
                    PCW DIMENSION OF TL IN CALLING PROGRAM. MIN=24.
C
   KTL
C
                    ROW DIMENSION OF TS IN CALLING PROGRAM. MIN=NRST.
   KTS
          = INPUT
C
C
      NERROR EXPLANATION
C
   1 = SIZE LIMITATION EXCEEDED.
C
   2 = NAMEK IMPROPERLY DEFINED.
      NRST = 24
                                                                     NERROR=1
      if (KS .LT. 24 .CR. KTL .LT. 24 .OR. KTS .LT. NRST) GO TO 499
      DO 5 J=1,24
      DO 5 I=1,24
    5 S(I_*J) = 0.0
      IF (NAMEK .EC. 6HKI
                               1 60 TO 110
                                                                     NERROR=2
      60 TO 999
C
  110 DC 200 I=1,3
      CW(1,1) = CJ(1,1)
      EW(1,1) = EJ(1,1)
      CW(1,2) = CJ(1,2)
      EW(1,2) = FJ(1,2)
      CW(1,3) = CJ(1,3)
  200 EW(1,3) = FJ(1,3)
                   (CW,EY,TMEM,TEEN,E,ANU,NAMEK,NAMEST,W1,TL,TS,NRSTX,
      CALL STF2
                    KCW, KCW, KWI, KTL, KTS)
      CALL REVAUD (.F, W1, IV1, IV1, S, 18, 18, 24, 24, 18, KS)
      DO 201 I=1,3
      CW(I,1) = CJ(I,1)
      EW(I,1) = FJ(I,1)
      CW(1,2) = CJ(1,3)
      EW(I,2) = EJ(I,3)
      CW(1,3) = CJ(1,4)
  201 \text{ EW}(1,3) = \text{EJ}(1,4)
                   (CW, EW, TMEM, THEN, F, ANU, NAMEK, NAMEST, W1, TL, TS, NRSTX,
      CALL STF2
                    KCW, KCW, KW1, KTL, KTS)
      CALL REVAPD (.5, WI, IV2, IV2, S, 18, 18, 24, 24, 18, KS)
      DO 203 1=1.3
      CW(I,I) = CJ(I,I)
      EW(1,3) = FJ(1,1)
      CW(I,2) = CJ(I,2)
      EW(1,2) = EJ(1,2)
      CW(1,3) = CJ(1,4)
  203 EW(I,3) = EJ(I,4)
      CALL STF2
                   (CW, EW, TM FM, TBEN, E, ANU, NAMEK, NAMEST, W1, TL, TS, NRSTX,
                    KCW, KCW, KWI, KTL, KTS)
      CALL REVADD (.5, W1, IV3, IV3, S, 18, 18, 24, 24, 18, KS)
      DD 205 I=1,3
      CW(I,1) = CJ(I,2)
      EW(I,1) = EJ(I,2)
```

```
CW(1,2) = CJ(1,3)
      EW(1,2) = EJ(1,3)
      CW(I,3) = CJ(I,4)
  205 \text{ EW(1,3)} = \text{EJ(1,4)}
                    (CW, EW, TMEM, TBEN, E, ANU, NAMEK, NAMEST, WI, TL, TS, NRSTX,
      CALL STF2
                    KCW, KCW, KW1, KTL, KTS)
      CALL REVADD (.5,W1,IV4,IV4,S, 18,18,24,24, 18,KS)
C
      DC 300 J=1,24
      DO 300 I=1,24
      TL(I,J) = 0.0
  300 TS(I,J) = 0.0
      RETURN
C
  999 CALL ZZBOMB (4HSTF3 ,NERROR)
      END
```

```
SUBROUTINE STE3A (CJ, EJ, TH, G, NAMEK, NAMEST, S, TL, TS, NRST,
                        KCJ.KEJ.KS.KTL.KTS)
      DIMENSION CJ(KCJ,1), EJ(KEJ,1), S(KS,1), TL(KTL,1), TS(KTS,1)
C
   SUBROUTINE TO CALCULATE FINITE ELEMENT ...
C
      STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION MATRIX),
C
      LOCAL LOAD TRANSFORMATION MATRIX,
C
C
      STRESS TRANSFORMATION MATRIX.
   FOR A PECTANGULAR SHEAF PANEL ELEMENT WITH UNRESTRAINED BOUNDARIES.
C
   STIFFNESS MATRIX IS IN GLOBAL COORDINATE DIRECTIONS.
   GLOBAL COURDINATE ORDER IS
      (U, V, W) JCINT 1, THEN JOINT 2, 3, 4.
   WHERE U.V.W ARE TRANSLATIONS.
   GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT PANEL VERTICES IN
   GLOFAL COORDINATE DIFECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C
   DIRECTIONS.
   ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C
      (PU,PV,PW) JOINT 1, THEN JOINT 2, 3, 4.
C
C
   WHERE P IS FORCE.
   LOCAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT PANEL VERTICES IN
C
   LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
C
   DIRECTIONS.
   ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS
C
      PX1,PX2,PX3,PX4, PY1,PY2,PY3,PY4
C
   WHERE P IS FORCE. X GOES FROM 1 TO 2. Y GOES FROM 1 TO 4.
C
   STRESS TRANSFORMATION MATPIX RELATES PANEL SHEAR STRESS (CONSTANT) IN
   LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORD DIRECTIONS.
   EULER ANGLE CONVENTION IS GLOBAL X.Y.2 PERMUTATION.
   CALLS FORMA SUPROUTINES ATXBA1,DCDS3C,K3C1,MULTA,ZZBOMB.
   DEVELOPED BY RL WOHLEN. APRIL 1974.
C
C
   LAST PEVISION BY WA BENFIELD. MARCH 1976.
C
C
      SURROUTINE ARGUMENTS
C
          = INPUT MATRIX OF GLCPAL X,Y,Z COORDINATES AT PANEL JOINTS.
   CJ
C
                   ROWS 1,2,3 CORRESPOND TO X,Y,Z COORDINATES.
                   COLS 1,2,3,4 CORRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C
C
          = INPUT
                   MATRIX OF EULER ANGLES (DEGREES) AT PANEL JOINTS.
   EJ
                   ROWS 1,2,3 CORRESPOND TO GLOBAL X,Y,Z PERMUTATION.
C
C
                   CCLS 1,2,3,4 CCRRESPOND TO JOINTS 1,2,3,4. SIZE(3,4).
C
          = INPUT
   TH
                   PANEL THICKNESS.
C
          = INPUT
                   SHEAR MODULUS OF ELASTICITY.
   G
C
   NAMEK = INPUT
                   TYPE OF STIF MATRIX WANTED.
C
                   = K1, USES K3C1.
C
   NAMEST = INPUT
                   OPTION FOR STRESS TRANSFORMATION.
                              BF 6HNDSTRS ,ND STRESS TRANS CALCULATED.
C
                   = 6H
          = OUTPUT STIFFNESS MATRIX (SAME AS GLOBAL LOAD TRANSFORMATION
C
                   MATRIX). SIZE(12,12).
C
          = OUTPUT LUCAL LOAD TPANSFORMATION MATRIX. SIZE(8,12).
C
   TL
          = OUTPUT STRESS TRANSFORMATION MATRIX. SIZE(1,12).
C
   TS
          = OUTPUT NUMBER OF ROWS (1) IN STRESS TRANSFORMATION MATRIX.
C
   NPST
                   ROW DIMENSION OF CJ IN CALLING PROGRAM.
C
   KCJ
          = IMPUT
                   ROW DIMENSION OF EJ IN CALLING PROGRAM.
C
          = INPUT
   KEJ
                   POW DIMENSION OF S IN CALLING PROGRAM. MIN=12.
C
   K S
          = INPUT
                   POW DIMENSION OF THE IN CALLING PROGRAM. MIN=8.
C
   KTL
          = INPUT
                  POW DIMENSION OF TS IN CALLING PROGRAM. MIN=1.
   KTS
          = INPUT
```

```
C
      NEFROR EXPLANATION
C
  1 = SIZE LIMITATION EXCEEDED.
C
  2 = NAMEK IMPROPERLY DEFINED.
C
      NRST = I
                                                                NERROR=1
      1F (KS .LT. 12 .OR. KTL .LT. & .OR. KTS .LT. NRST) GO TO 999
      SL12 = SQRT((CJ(1,2)-CJ(1,1))**2 + (CJ(2,2)-CJ(2,1))**2
                                      + (CJ(3,2)-CJ(3,1))**2)
     SL14 = SQET((CJ(1,4)-CJ(1,1))**2 + (CJ(2,4)-CJ(2,1))**2
                                      + (CJ(3,4)-CJ(3,1))**2)
      IF (NAMEK .EQ. 6HK1 ) GO TO 110
                                                                NERROR=2
     GD TO 999
C
  110 CALL K3C1 (SL12, SL14, TH, G, TL, TS, KTL, KTS)
                                                                        TL=K
C
      CALL DCOS3C (CJ,EJ,S,KCJ,KEJ,KS)
                                                                        S = DC
      CALL MULTA (TL,S,8,8,12,KTL,KS)
      IF (NAMEST .EC. 6H .OR. NAMEST .EC. 6HNOSTRS) GO TO 210
      CALL MULTA (TS,S,NRST,8,12,KTS,KS)
  210 CALL ATXEAL (S,TL,E,12,KS,KTL)
      RETURN
  999 CALL ZZPOME (6HSTF3A ,NERROR)
      END
```

```
SUPRCUTINE TEGFOM (CJ.JM.
                                    VL,DV,
                                                 KCJ,
                                                         IFBAD)
                                              DV(1)
      DIMENSION CU(KCJ,1), JM(
                                  1),
      DIMENSION
                     R12(3),R13(3),R14(3)
      DATA EPS / 1.E-5 /
  SUPROUTINE TO DETERMINE THE VOLUME AND VOLUME CHANGE COEFFICIENTS OF
  A TETRAHEDRON.
   CALLS FORMA SUBPOUTINES VCROSS. VDOT
   DEVELOPED BY C.S. BODLEY. FEBRUARY 1974.
   LAST REVISION BY R A PHILIPPUS. AUGUST 1974.
C
      SUBROUTINE ARGUMENTS
C
   CJ
         = INPUT MATEIX OF JOINT COORDINATES. SIZE(3.8).
         = INPUT VECTOR OF JOINTS DEFINING A TETRAHEDRON. SIZE (4).
C
   JM
         = OUTPUT VOLUME OF TETRAHEDRON DEFINED BY JM.
C
   ٧L
         = OUTPUT VECTOR OF VOLUME CHANGE COEFFICIENTS.
C
   DV
C
         = INPUT FOW DIMENSION SIZE OF CJ IN CALLING PROGRAM. MIN = 3.
   KCJ
   IFBAD = OUTPUT
           = 0 . THE TETRAHEDRON VERTICIES ARE NOT NUMBERED ACCORDING
                 TO THE ESTABLISHED CONVENTION, OR LIE IN A PLANE.
C
C
      J1 = JM(1)
                  )
      J2 = JM(2)
                  )
      J3 = JM13
                  )
      J4 = JM(4)
                  )
      DC 5 I=1.3
      P12(1) = CJ(1,32) - CJ(1,31)
      R13(I) = CJ(I,J3) - CJ(I,J1)
    5 R14(I) = CJ(I,J4) - CJ(I,J1)
C
      CALL VCROSS (R12,R13,DV(10),VAMAG,VPMAG,VZMAG,SINAB)
                  (DV(10),R14,VCL,VAMAG,VBMAG,COSAB)
      CALL VDCT
      IF (VOL.LE.EPS) IFRAD=0
      ٧L
            = VOL/6.
C
      CALL VCFOSS (F13,P14,DV(4), VAMAG,VPMAG,VZMAG,SINAB)
      CALL VCPOSS (R14,R12,DV(7), VAMAG, VBMAG, VZMAG, SINAB)
      DO 10 I=1.3
   10 DV(I) = -DV(I+3) - DV(I+6) - DV(I+9)
      DO 15 I=1,12
   15 DV(1) = DV(1)/6.
C.
      RETURN
      END
```

```
SUBROUT INE TRNGL
                        (XYZ, JDOF, EUL, NUTEL, NJ,
                         NUTMX, NUTKX, NUTBX, NUTLT, NUTST,
                          W, T, S, KX, KJ, KE, KW)
      DIMENSION XYZ(KX,1),JDOF(KJ,1),EUL(KE,1),W(KW,1),T(KW,1),S(KW,1)
      DIMENSION (J(3,3), EJ(3,3), IVI(18)
      DATA MAMSE/6HTRNGL /, NRW,NRLT/18,18/, IBLNK/6H
                                                             /. KCJ/3/
      DATA MIT MOT/5,6/
C
C
   SUBPOUTENCE TO CALCULATE (ON OPTION) FINITE ELEMENT ...
C
      MASS MATRICES AND IVECS (ON NUTMX).
C
      STIFFNELS MATRICES (SAME AS GLOBAL LOAD TRANSFORMATION MATRICES)
C
      AND IVECS (ON NUTKX).
C
      UNIT LOAD BUCKLING MATRICES AND IVECS (ON NUTBX), (NOT YET)
C
      LOCAL LOSS TRANSFORMATION MATRICES AND IVECS (ON NUTLT).
C
      STRESS TP INSFORMATION MATRICES AND IVECS (ON NUTST).
C
   FOR COMPINED MEMBRANE-BENDING TRIANGLE PLATE ELEMENTS.
C
   MASS, STIFFNESS, BUCKLING MATRICES ARE IN GLOBAL COORDINATE
C
   DIRECTIONS.
C
   GLOBAL COORDINATE ORDER IS
C
      (U,V,N,P,H,R) JOINT 1, THEN JOINT 2, 3.
   WHERE U, V, W AFE TRANSLATIONS AND P, Q, P APE ROTATIONS.
C
   IVEC GIVES ELEMENT DOT INTO GLOBAL DOF. EXAMPLES...
C
C
      IVEC(6)=834 PLACES ELEMENT DOF 6 INTO GLOBAL DOF 834.
                  OMITS ELEMENT DOF 3 FROM GLOBAL DOF. THIS CONSTRAINS
C
      1VEC (3!=0
                  ELEMENT DOF 3 TO ZERO MOTION.
C
C
   GLOBAL LOAD TRANSFORMATION MATRIX RELATES LOADS AT TRNGL VERTICES IN
C
   GLOBAL COURDINATE DIRECTIONS TO DEFLECTIONS IN THE GLOBAL COORDINATE
C
   DIRECTIONS.
   ROW ORDER IN GLOBAL LOAD TRANSFORMATION MATRIX IS
C
C
      (PU, PV, PW, MP, MQ, MR) JCINT 1, THEN JOINT 2,3.
C
   WHERE P IS FURTE AND M IS MOMENT.
C
   LOCAL LOAD TEANSFORMATION MATRIX RELATES LOADS AT TRNGL VERTICES IN
C
   LOCAL COORDINATE SYSTEM TO DEFLECTIONS IN THE GLOBAL COORDINATE
C
   DIRECTIONS.
   ROW ORDER IN LOCAL LOAD TRANSFORMATION MATRIX IS
C
C
      (PX, PY, MZ) JOINT 1 THEN 2,3, MEXT
C
      (PZ,MX,MY) JOINT 1 THEN 2,3.
C
   WHERE P IS FORCE AND ! IS MOMENT.
   STRESS TRANSFORMATION WATRIX RELATES STRESS AT TRNGL VERTICES IN LOCAL
C
C.
   COORDINATE SYSTEM TO DEFLECTIONS IN THE CLOPAL COORDINATE DIRECTIONS.
   ROW ORDER IN STRE A TRANSFORMATION MATRIX IS
C
C
      (SIGMA-X, SIGMA-Y, TAU-XY) FOR (Z=TBEN/2) AT JOINT 1,
C
      THEM JOINT ?.3.
      (SICMA-X, GIGMA-Y, TAU-XY) FOR (Z=-TBEN/2) AT JCINT 1.
C
C
      THEN JOINT 2.3.
C
   WHERE SIC : IS NORMAL STRESS AND TAU IS SHEAR STRESS.
C
   DATA AF ANGEMENT ON NUTMX, NUTKX, NUTBX, NUTLT, NUTST FOR EACH
C
   FINITE FLEMENT IS (W=M,K,B,LT,ST)
C
      WRITE (NUTWX) NAMEW, NFL, NR, NC, NAMEL, (IBLNK, I=1,5),
                     ((W(1,J),I=1,NR),J=1,NC),(IVEC(I),I=1,NC)
   CALLS FORMA SUBPOUTINES MASZ, PAGEHD, STF2, ZZBOMB.
C
   DEVELOPED PY WA BENFIELD, CS BODLEY, RL WOHLEN. FEBRUARY 1973.
C
C
   LAST REVISION BY RL WOHLEN. MAY 1976.
C
```

```
INPUT DATA READ IN THIS SUBROUTINE FROM NUTEL. IF NUTEL = 5, DATA IS
C
   READ FROM CARDS.
C
      NAMEM, NAMEK, NAMELT, NAMEST, NAMEB
                                                  FORMAT (5(A6,4X)
C
                                                  FORMAT (3(5X,E10))
      RO, E, ANU
C
                                                  FORMAT (3(5X, E10))
      TMASC, TMEMC, TBENC
C
   20 NEL, J1, J2, J3, TMASV, TMEMV, TBENV
                                                  FORMAT (415,3E10)
C
      IF (J1 .EQ. O) RETURN
      GD TO 20
C
C
C
   DEFINITION OF INPUT VARIABLES.
   NAMEM = TYPE OF MASS MATRIX WANTED.
C
C
            = M1, D1AGONAL LUMPED.
C
            = M2, CONSISTENT.
C
                       OR 6HNOMASS, NO MASS MATRIX CALCULATED.
            = 6H
C
         = TYPE OF STIFFNESS MATRIX WANTED.
   NAMEK
C
            = K1, QUADRATIC DISPLACEMENT FOR MEMBRANE, CUBIC
C
                  DISPLACEMENT FOR BENDING.
C
            = 6H
                       OR 6HNOSTIF, NO STIFFNESS MATRIX CALCULATED.
C
   NAMELT = IDENTIFICATION NAME FOR LOAD TRANSFORMATION MATRICES.
                       OR 6HNOLOAD, NO LOAD TRANSFORMATIONS CALCULATED.
C
            = 6H
C
   NAMEST = IDENTIFICATION NAME FOR STRESS TRANSFORMATION MATRICES.
C
                       OR 6HNOSTRS, NO STRESS TRANSFORMATIONS CALCULATED.
            = 6H
C
          = TYPE OF BUCKLING MATRIX WANTED.
   NAMER
C
            = 6H
                       OR 6HNOBUCK, NO BUCKLING MATRIX CALCULATED.
C
   RO
          = MASS DENSITY.
C
          = YOUNGS MODULUS OF ELASTICITY.
   ANU
C
          = PCISSONS RATIO. (E/2G)-1.
                               THICKNESS, (CONSTANT).
C
   TMASC
         = EFFECTIVE MASS
C
   TMASV
         = EFFECTIVE MASS
                               THICKNESS, (VARIABLE).
            IF .LE. U., TMASC IS USED.
C
C
   TMEMC
         = EFFECTIVE MEMBRANE THICKNESS, (CONSTANT).
C
         = FFFECTIVE MEMBRANE THICKNESS, (VARIABLE).
   TMEMV
C
            IF .LF. O., TMEMC IS USED.
          = EFFECTIVE FENDING
C
                              THICKNESS, (CONSTANT).
   TBENC
                              THICKNESS, (VARIABLE).
         = EFFECTIVE BENDING
C
   TBENV
            IF .LE. O., TEENC IS USED.
C
C
          = FINITE ELEMENT NUMBER. FOR REFERENCE ONLY, NOT USED IN
   NEL
C
            CALCULATIONS. WRITTEN ON NUTMX, ETC.
C
          = JOINT NUMBER AT TRIANGLE VERTEX 1.
   Jl
          = JOINT NUMBER AT TRIANGLE VERTEX 2.
C
   J2
          = JUINT NUMBER AT TRIANGLE VERTEX 3.
C
   j3
C
   EXPLANATION OF INPUT FORMATS. NUMBER INDICATES CARD COLUMNS USED.
C
C
      I = INTEGER DATA, RIGHT ADJUSTED.
C
      E = DECIMAL POINT DATA, ANYWHERE IN FIELD. EXPONENT RIGHT ADJUSTED.
C
      X = CAPD COLUMNS SKIPPED.
   C
C
C
      SUPPOUTINE ADCUMENTS (ALL INPUT)
C
   XYZ
          MATRIX OF JOINT GLOBAL X,Y,Z LOCATIONS. ROWS CORRESPOND
C
            TO JOINT NUMBERS. COLUMNS 1,2,3 COPRESPOND TO THE JOINT
C
            X,Y,Z LOCATIONS RESPECTIVELY. SIZE(NJ,3).
C
   JDOF
          = MATRIX OF JOINT GLOBAL DEGREES OF FREEDOM. ROWS CORRESPOND
            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE JOINT
C
C
            TRANSLATION DOFS AND COLUMNS 4,5,6 CORRESPOND TO THE JOINT
```

```
RCTATION DOFS. SIZE (NJ,6).
          = MATRIX OF JOINT EULER ANGLES (DEGREES). ROWS CORRESPOND
C
   EUL
C
            TO JOINT NUMBERS. COLUMNS 1,2,3 CORRESPOND TO THE
C
            GLOBAL X,Y,Z PERMUTATION. SIZE(NJ,3).
          = LOGICAL NUMBER OF TAPE CONTAINING FLEMENT INPUT DATA FOR
C
   NUTEL
C
            THIS SUBPOUTINE. IF NUTEL = 5, DATA IS READ FROM CARDS.
          = NUMBER OF JOINTS OF ROWS IN MATRICES (XYZ), (JDOF), (EUL).
C
   NJ
C
   NUTMX
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
C
            MASS MATPICES AND IVECS ARE OUTPUT.
            NUTMX MAY BE ZERO IF MASS MATRIX IS NOT FORMED.
C
C
            USES FORTRAN READ, WRITE.
C
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
   NUTKX
C
            STIFFNESS MATRICES (SAME AS GLOBAL LOADS TRANSFORMATION
C
            MATRICES) AND IVECS ARE OUTPUT.
C
            NUTKX MAY BE ZERO IF STIFFNESS MATRIX IS NOT FORMED.
C
            USES FORTRAN READ, WRITE.
C
   NUTBX
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT UNIT LOAD
C
            BUCKLING MATRICES AND IVECS ARE DUTPUT.
C
            NUTBX MAY BE ZERO IF BUCKLING MATRIX IS NOT FORMED.
C
            USES FORTRAN READ, WRITE.
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT LOCAL
C
   NUTLT
            LOAD TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
C
            NUTLT MAY BE ZERO IF LOAD TRANSFORMATIONS ARE NOT FORMED.
C
C
            USES FORTRAN READ, WRITE.
C
          = LOGICAL NUMBER OF UTILITY TAPE ON WHICH ELEMENT
   NUTST
C
            STRESS TRANSFORMATION MATRICES AND IVECS ARE OUTPUT.
            NUTST MAY BE ZERO IF STRESS TRANSFORMATIONS ARE NOT FORMED.
C
C
            USES FORTRAN READ, WRITE.
          = MATRIX WORK SPACE. MIN SIZE(18,18).
C
          = MATRIX WORK SPACE. MIN SIZE(18,18).
C
   T
C
          = MATRIX WOPK SPACE. MIN SIZE(18,18).
C
   ΚX
          = POW DIMENSION OF XYZ IN CALLING PROGRAM.
C
   KJ
          = ROW DIMENSION OF JOOF IN CALLING PROGRAM.
C
          = ROW DIMENSION OF EUL IN CALLING PROGRAM.
   KE
C
          = ROW DIMENSION OF W, T, AND S IN CALLING PROGRAM. MIN=18.
   KW
C
      NERPOR EXPLANATION
C
C
   1 = JOINT NUMBER GREATER THAN NUMBER OF JOINTS.
C
   2 = MASS MATRIX FURMED, NUTMX .LE. ZERO.
C
   3 = STIFFNESS MATRIX FORMED, NUTKX .LE. ZERO.
C
   4 = LT MATRIX FORMED, NUTLT .LE. ZEPO.
C
   5 = ST MATRIX FORMED, NUTST .LE. ZERO.
 1001 FORMAT (5(A6,4X))
 1002 FORMAT (3(5x,E10.0))
 1003 FORMAT (415.3E10.0)
 2001 FUPMAT (//32X 49HINPUT DATA FOR COMBINED MEMBRANE-BENDING TRIANGLE
                     15H PLATE ELEMENTS)
 2002 FORMAT (//26X 49HINPUT DATA FOR COMBINED MEMBRANE-BENDING TRIANGLE
                     27H PLATE ELEMENTS (CONTINUED))
 2003 FOPMAT (/ 13x7HMASS = A6, 13x7HST1F = A6, 6X13HLOAD TRANS = A6,
                3X15HSTRESS TRANS = A6, 3X11HPUCKLING = A6,
              / 15X4HP0 = E10.3, 13X3HE = F10.3,
              / 10 \times 0 + T (MASS) = E10.3, 12 \times 4 + NU = E10.3,
              / 32X13HT(MEMBRANE) = E10.3,
```

```
/ 33X12HT(BENDING) = E10.3
               //18X 7HELEMENT 5X 7HJOINT 1 5X 7HJOINT 2 5X 7HJOINT 3
                  5X 7HT(MASS) 6X 11HT(MEMBRANE) 5X 10HT(BENDING)
                /18X 6HNUMBER 36X 3(5X 10H(VARIABLE) ) )
 2004 FORMAT (18X 4(15,7X),3(F10.3,5X) )
 2005 FORMAT (18X 4(15,7X) )
C
   READ AND WRITE FINITE ELEMENT DATA.
C
      NTIME = i.
      CALL PAGETO
      WRITE (NO:, ?001)
      READ (NUTFI, 1001) NAMEM, NAMEK, NAMELT, NAMEST, NAMEB
      READ (MUTEL, 1002) RO, E, ANU
      READ (NUTEL, 1002) TMASC, TMEMC, TBENC
      WRITE (NOT-2003) NAMEM-NAMEK.NAMELT.NAMEST.NAMEB.
                        RO, E, TMASC, ANU, TMEMC, TBENC
   20 READ (NUTEL, 1003) NEL, J1, J2, J3, TMASV, TMEMV, TBENV
      NO THIK = I
      IF (TMASV.LE.O. .AND. TMEMV.LE.O. .AND. TBENV.LE.O.) NO THIK=0
      IF (J1 .LE. G) RETURN
      NLINE = NLINE + 1
      IF (NLINE .LE. 42) GO TO 30
      CALL PAGEND
      WRITE (NOT, 2002)
      WRITE (NOT, 2003) NAMEM, NAMEK, NAMELT, NAMEST, NAMEB,
                        RC, E, TMASC, ANU, TMEMC, TEENC
      NLINE = 0
   30 IF (NO THIK.EQ.1)
     *WRITE (NOT, 2004) NFL, J1, J2, J3, TMASV, TMEMV, TBENV
      IF (NO THIK.EQ.O) WRITE (NOT, 2005) NEL, J1, J2, J3
                                                                    NERROR=1
      IF (J1 .GT. NJ .DR. J2 .GT. NJ .OR. J3 .GT. NJ) GO TO 999
C
   SET THICKNESSES.
      TMAS = TMASC
      TMEM = TMEMC
      TREN = TRENC
      IF (TMASV.GT.C.) TMAS=TMASV
      TF (TMEMV.GT.O.) TMEM=TMEMV
      TRENV.GT.O.) THEN = TRENV
   FORM FINITE FLEMENT COORDINATE LOCATIONS, EULER ANGLES, REVADD IVEC.
      DO 42 I=1,3
      CJ(I,I) = YYZ(JI,I)
      CJ(1,2) = XYZ(J2,1)
      CJ(1,3) = XYZ(J3,I)
      EJ(I,I) = EUL(JI,I)
      EJ(1,2) = EUL(J2,1)
   42 EJ(I,3) = EUL(J3,1)
      DO 44 I=1,6
                = JDCF(J1,I)
      IV1(I)
      IV1(I+6) = JD0F(J2,1)
   44 \text{ IV1}(I+12) = \text{JDOF}(J3,I)
C
   FORM MASS MATRIX (W).
```

```
IF (NAMEM . EQ. 6H
                                .CR. NAMEM .EQ. 6HNOMASS) GO TO 110
      CALL MAS2
                 (CJ, EJ, TMAS, RO, NAMEM, W, T, S, KCJ, KCJ, KW, KW, KW)
                                                                    NERROR=2
      IF (NUTMX .LE. 0) GE TO 999
      WRITE (NUTMX) NAMEM, NEL, NRW, NRW, NAMEL, (IBLNK, I=1,5),
                     ((W(1,J),I=1,NRW),J=1,NRW),(IV1(1),I=1,NRW)
C
   FORM STIFFNESS MATRIX (W), LOCAL LOAD TRANSFORMATION MATRIX (T),
  STRESS TRANSFORMATION MATRIX (S).
  110 IF (NAMEK .EQ. 6H
                                .CR. NAMEK .EQ. 6HNOSTIF) GO TO 20
      CALL STF2
                   (CJ, EJ, TMEM, TBEN, F, ANU, NAMEK, NAMEST, W, T, S, NRST,
                    KCJ,KCJ,KW,KW,KW)
                                                                    NERROR=3
      IF (NUTKX .LE. C) GO TO 999
      WRITE (NUTKX) NAMEK, NEL, NPW, NRW, NAMEL, (JELNK, I=1,5),
                     ((W(I,J),I=1,NRW),J=1,NRW),(IV1(I),I=1,NRW)
      IF (NAMELT .EG. 6H
                                 .OR. NAMELT .EQ. 6HNOLOAD) GO TO 115
                                                                    NERROR=4
      IF (NUTLT .LE. 0) GC TO 999
      WRITE (NUTLT) NAMELT, NEL, NRLT, NRW, NAMEL, (IBLNK, I=1,5),
                     ((T(I,J),I=1,NRLT),J=1,NRW),(IV1(I),I=1,NRW)
  115 IF (NAMEST .EQ. 6H
                                 .CR. NAMEST .EG. 6HNDSTRS) SO TO 20
                                                                    NERROR=5
      IF (NUTST .LF. 0) GO TO 999
      WRITE (NUTST) NAMEST, NEL, NRST, NRW, NAMEL, (IBLNK, I=1,5),
                     \{(S(I,J),I=1,NRST),J=1,NRW\},(IV1(I),I=1,NRW)\}
      GO TO 20
C
  999 CALL ZZBOME (6HTRNGL , NEKROR)
      END
```